2 SITE BACKGROUND

This section provides detailed information about the INEEL including historical information about the INEEL's evolving missions, physical landscape, biological information, demography, land use, and cultural resources. The preponderance of this information also applies to WAG 7. When significant information unique to the RWMC is discussed in detail, the facility has been included in subsection headings.

The INEEL, originally established in 1949 as the National Reactor Testing Station (NRTS), is a DOE-managed reservation that has historically been devoted to energy research and related activities. The NRTS was redesignated as the Idaho National Engineering Laboratory (INEL) in 1974 to reflect the broad scope of engineering activities taking place at various on-Site facilities. In 1997, the INEL was renamed the Idaho National Engineering and Environmental Laboratory in keeping with contemporary emphasis on environmental research. Historical testing at the INEEL demonstrated that nuclear power could be used safely for generating electricity and for other peaceful applications.

More nuclear reactors and a wider variety of reactor types have been built at the INEEL than at any other single location in the world. As of January 2002, only one INEEL reactor is operating. The remaining reactors are idle or have been phased out because their missions were completed (Irving 1993). Spent nuclear fuel management, hazardous and mixed waste management and minimization, cultural resources preservation, environmental engineering, protection, and remediation, and long-term stewardship are challenges addressed by current INEEL activities (DOE-ID 1996). The laboratory's future mission, delivering science-based solutions to the current challenges of DOE, other federal agencies, and industrial clients, encompasses four areas: environmental quality, energy resources, national security, and science (INEEL 2002).

Three federal government contractors operate facilities at the INEEL. Bechtel BWXT Idaho, LLC (BBWI) is the management and operating Site-services contractor. Bechtel Bettis operates the Naval Reactors Facility (NRF), and the University of Chicago operates Argonne National Laboratory-West (ANL-W). These contractors conduct various programs at the INEEL under the supervision of three DOE offices: DOE-ID, the DOE-Pittsburgh Naval Reactors Office, and the DOE-Chicago Operations Office, respectively. Responsible for the INEEL, DOE-ID authorizes all government contractors to operate at the Site. A variety of programmatic and support services provided by BBWI are related to nuclear reactor design and development, nonnuclear energy development, materials testing and evaluation, operational safety, radioactive waste management, and environmental restoration.

2.1 Location and Description

The INEEL is located in southeastern Idaho (see Figure 1-1) and occupies 2,305 km^2 (890 mi^2) in the northeastern region of the Snake River Plain. Regionally, the INEEL is nearest to the cities of Idaho Falls and Pocatello and to U.S. Interstate Highways I-15 and I-86. The Site extends nearly 63 km (39 mi) from north to south, is about 58 km (36 mi) wide in its broadest southern portion, and occupies parts of five southeast Idaho counties: Butte, Bingham, Bonneville, Jefferson, and Clark. Most of the INEEL lies within Butte County. Approximately 95% of the INEEL has been withdrawn from the public domain. The remaining 5% includes public highways (U.S. 20 and 26 and Idaho 22, 28, and 33) and the Experimental Breeder Reactor I (EBR-I), which is a national historic landmark (Irving 1993). Neighboring lands are used primarily for farming, grazing, or are in the public domain (e.g., national forests and state-owned land).

The surface of the INEEL is a relatively flat, semiarid, sagebrush desert. Predominant relief is manifested either as volcanic buttes jutting up from the desert floor or as unevenly surfaced basalt flows or flow vents and fissures. Elevations on the INEEL range from 1,460 m (4,790 ft) in the south to 1,802 m (5,913 ft) in the northeast, with an average elevation of 1,524 m (5,000 ft) above sea level (Irving 1993). Mountain ranges bordering the INEEL on the north and west are the Lost fiver Range, the Lemhi Range, and the Beaverhead Mountains of the Bitterroot Range (see Figure 1-1).

Surface water features on the INEEL include the Little Lost fiver, Big Lost fiver and Birch Creek. Normally, water is diverted for irrigation or hydropower before reaching the INEEL and only flows onto the reservation when sufficient snow pack occurs to provide spring runoff. The Big Lost fiver enters the Site from the west and terminates at the Lost fiver Sinks in the northwest portion of the INEEL, where water either evaporates or infiltrates into the Snake fiver Plain Aquifer (SRPA). Flow from the Big Lost fiver can be diverted to Spreading Areas A, B, C, and D in the southern portion of the Site west and southwest of the RWMC. The locations of the surface water features and spreading areas are illustrated on Figure 1-1. The diversion system was constructed in 1958 to protect INEEL facilities from potential flooding. Birch Creek enters the Site from the north and also terminates on the INEEL.

The location of the INEEL relative to the aquifer is illustrated in the map on Figure 2-1. The SRPA, which consists of saturated basalt and sediments, is one of the largest aquifers in the United States (Irving 1993) and was classified as a sole-source aquifer by the EPA in 1991 (56 FR 50634). Generally, groundwater flows in the aquifer from the northeast to the southwest.

Lands acquired for the INEEL were originally under control of the U.S. Bureau of Land Management (BLM) and were withdrawn through public land orders in 1946, 1949, and 1950. Until these withdrawals, the land was used primarily as rangeland. Between 121,410 to 141,645 ha (300,000 to 350,000 acres) within the perimeter of the INEEL have been open to grazing through permits administered by the BLM. Since 1957, grazing has not been permitted in the central area of the INEEL. Covering approximately 1,386 km^2 (535 mi^2), this central area has been used historically as bombing and gunnery ranges. Currently, the largely undeveloped central portion of the INEEL is reserved for ecological studies of sagebrush-steppe ecosystems.

2.2 Physical Characteristics

2.2.1 Physiography

The INEEL is located in the Eastern Snake fiver Plain (ESRP), the largest continuous physiographic feature in southern Idaho. This large topographic depression extends from the Oregon border across Idaho to Yellowstone National Park and northwestern Wyoming. The ESRP, the eastern-most extension of the Columbia fiver Plateau Province (EG&G 1988), slopes upward from an elevation of about 762 m (2,500 ft) at the Oregon border to more than 1,981 m (6,500 ft) at Henry's Lake near the Montana-Wyoming border (Becker et al. 1996).

The INEEL is located entirely on the northern side of the ESRP and adjoins the Lost fiver, Lemhi, and Beaverhead mountain ranges to the northwest, which compose the northern boundary of the plain (see Figures 1-1 and 2-1). The portion of the Snake fiver Plain occupied by the INEEL may be divided into three minor physical provinces: a central trough that extends from southwest to northeast through the INEEL and two flanking slopes that descend to the trough, one from the mountains to the northwest and the other from a broad lava ridge on the plain to the southeast. The slopes on the northwestern flank of the trough are mainly alluvial fans originating from sediments of Birch Creek and the Little Lost fiver. Also forming these gentle slopes are basalt flows that spread onto the plain. Land formations on the southeast flank of the trough were created by basalt flows that spread from an eruption zone that extends

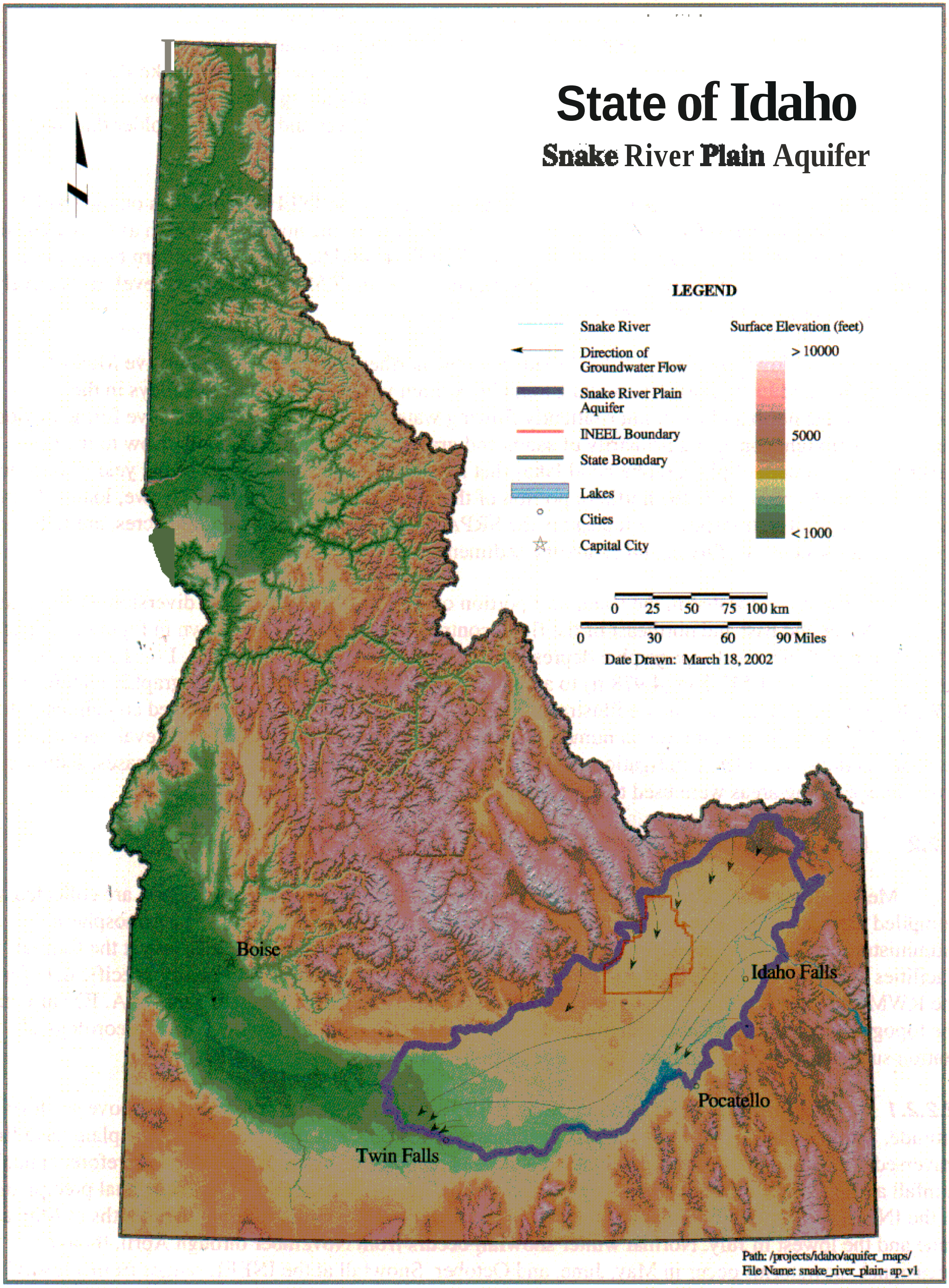

Figure 2-1. Location of the Idaho National Engineering and Environmental Laboratory on the Snake River Plain Aquifer in Idaho.

northeastward from Cedar Butte. Lavas that erupted along this zone built up a broad topographic swell directing the Snake River to its current course along the southern and southeastern edges of the plain. This ridge separates the drainage of mountain ranges northwest of the INEEL from the Snake fiver. Big Southern Butte and the Middle and East Buttes are aligned roughly along this zone; however, they were formed by viscous rhyolitic lavas extruded through the basaltic cover and are slightly older than the surface basalts of the plain.

With the exception of the buttes on the southern border of the INEEL, elevations on the INEEL range from 1,460 m (4,790 ft) in the south to 1,802 m (5,913 ft) in the northeast with an average elevation of 1,524 m (5,000 ft) above sea level (EG&G 1988). The East, Middle, and Big Southern buttes have elevations of 2,003 m (6,571 ft), 1,948 m (6,389 ft), and 2,304 m (7,559 ft) above sea level, respectively (VanHorn, Hampton, and Morris 1995).

The central lowland of the INEEL broadens to the northeast and joins the extensive Mud Lake Basin. The Big and Little Lost Rivers and Birch Creek drain into this trough from valleys in the mountains to the north and west. Intermittently flowing waters of the Big Lost fiver have formed a flood plain in this trough, consisting primarily of sands and gravels. Streams intermittently flow to the Lost fiver Sinks, a system of playa (ephemeral lakes that have water only during parts of the year or once in several years) depressions in the northern portion of the INEEL, east of the town of Howe, Idaho. There, the water evaporates, transpires, or recharges the SWA. Sinks cover several hundred acres, are flat, and consist of thick layers of fluvial and lacustrine sediments.

The RWMC is located in the southwest portion of the Site, southeast of the diversion dam on the Big Lost fiver and east and northeast of the flood control spreading areas, as shown in Figure 2-2. The RWMC lies within a local topographic depression circumscribed by basaltic ridges. Local elevations range from a low of 1,517.3 m (4,978 ft) to a high of 1,544.7 m (5,068 ft). The topographic features of the RWMC and surrounding terrain are illustrated in Figure 2-3. Enclosed by a constructed containment dike, the RWMC has been recontoured on numerous occasions because of disposal and retrieval operations, remedial actions, subsidence mitigation, and surface drainage modifications. In several cases, sediments from the spreading areas were used to augment native soils.

2.2.2 Meteorology and Climatology

Meteorological and climatological data for the INEEL and the surrounding region are collected and compiled from several meteorological stations operated by the National Oceanic and Atmospheric Administration field office in Idaho Falls. Three stations are located on the INEEL, one at the Central Facilities Area (CFA), one at Test Area North (TAN), and one at the RWMC. Facility-specific data for the RWMC are very similar to those representing the southern INEEL collected at the CFA. Because of the topographical similarity and proximity of WAG 7 to the CFA, data from the CFA meteorological station sufficiently describe meteorological conditions at the SDA (Magnuson 1993).

2.2.2.1 Precipitation. The location of the INEEL in the ESW, including altitude above sea level, latitude, and intermountain setting, affects the climate of the Site. Air masses crossing the plain have first traversed a mountain barrier and precipitated a large percentage of inherent moisture. Therefore, annual rainfall at the INEEL is light, and the region is classified as arid to semiarid. Average annual precipitation at the INEEL is 22.1 cm (8.7 in.). The rates of precipitation are the highest during the months of May and June and the lowest in July. Normal winter snowfall occurs from November through April, though occasional snowstorms occur in May, June, and October. Snowfall at the INEEL ranges from a low of about 17.3 cm (6.8 in.) per year to a high of about 151.6 cm (59.7 in.) per year, and the annual average is 70.1 cm (27.6 in.) (Clawson, Start, and ficks 1989).

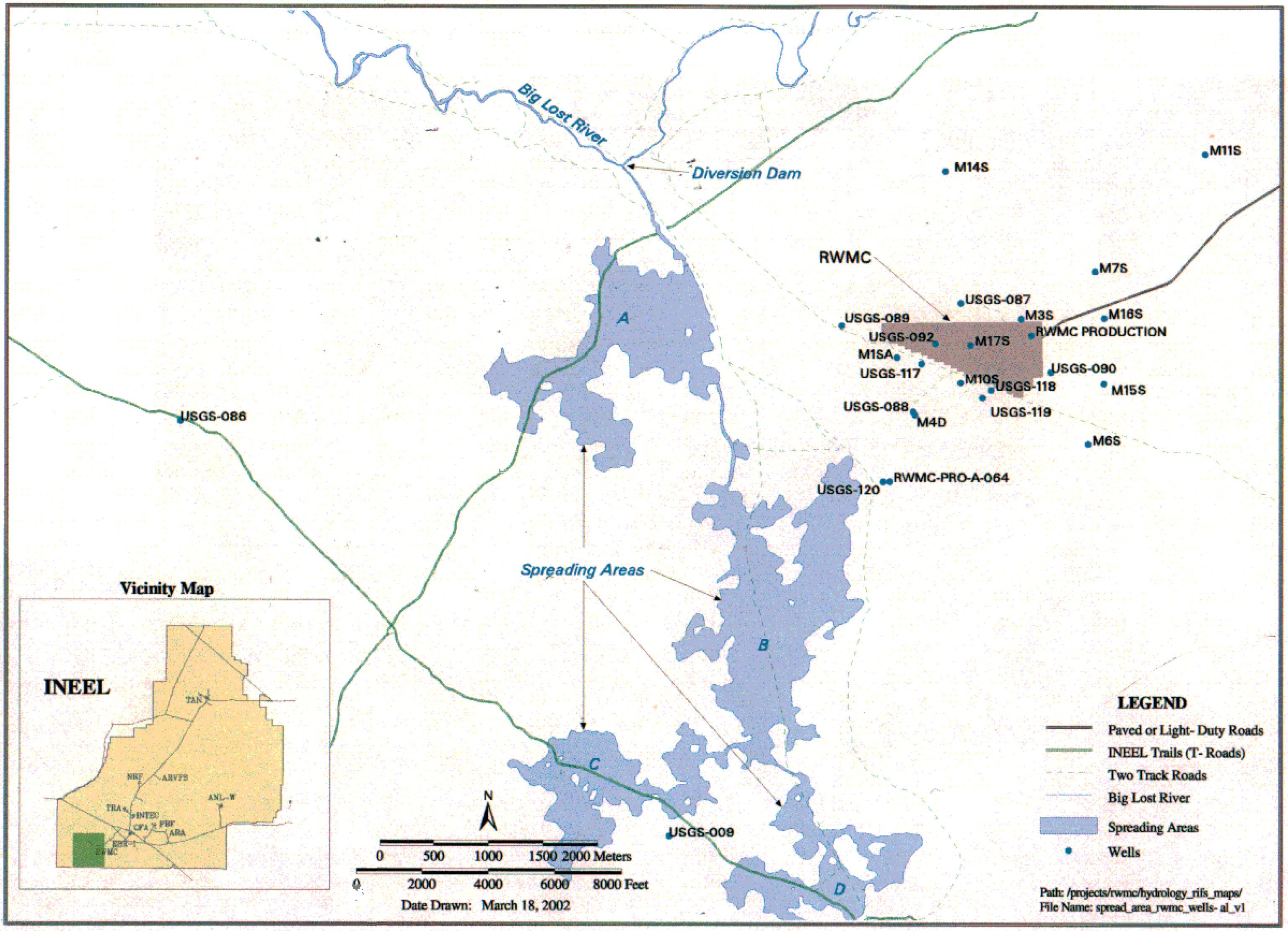

Figure 2-2. Location of Waste Area Group 7 relative to the Idaho National Engineering and Environmental Laboratory, the diversion dam on Big Lost River, and the flood control spreading areas.

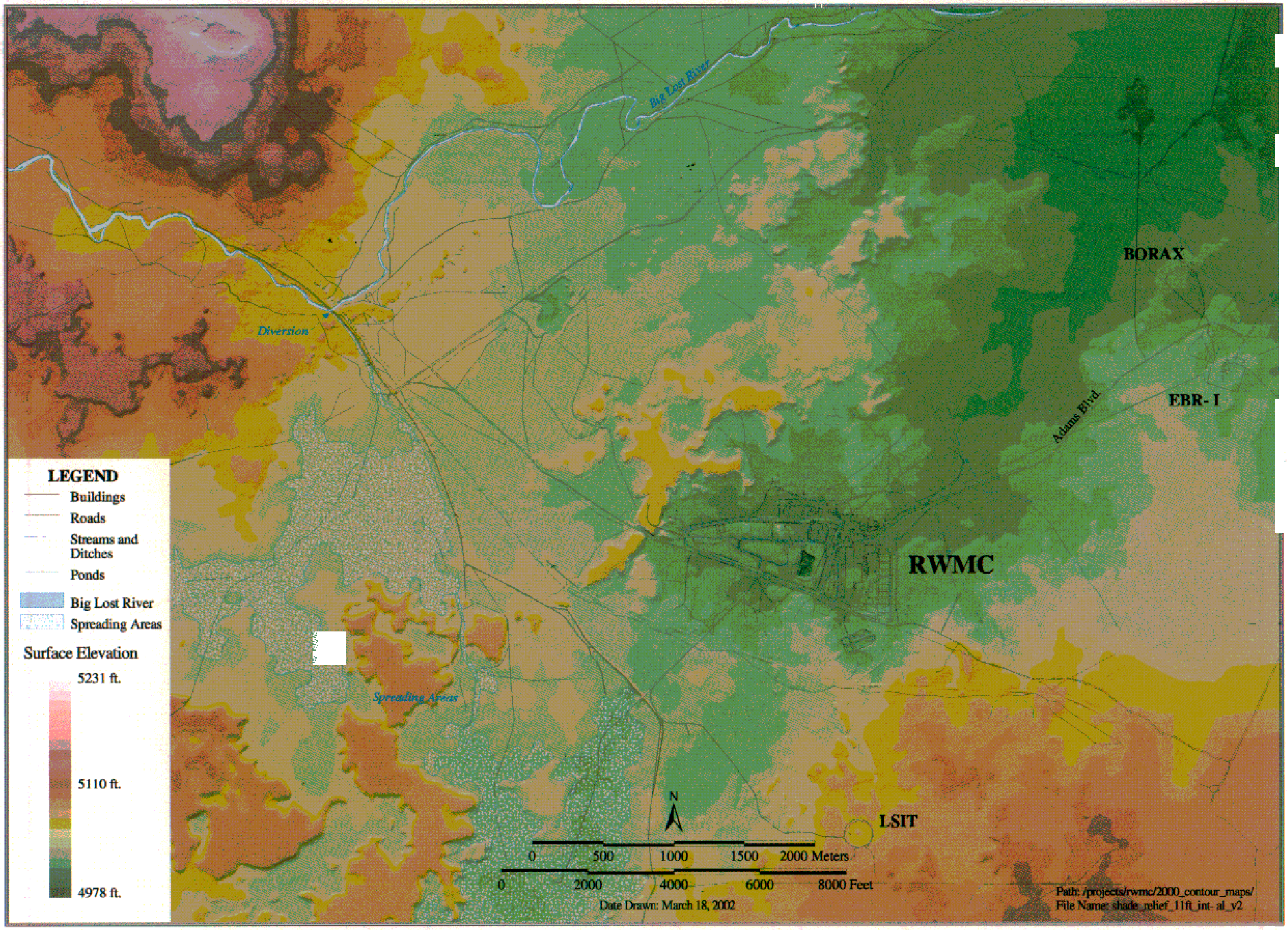

Figure 2-3. Topographic features of the Radioactive Waste Management Complex and surrounding terrain.

2.2.2.2 Temperature. The moderating influence of the Pacific Ocean produces a climate at the INEEL that is usually warmer in winter and cooler in summer than is found at locations of similar latitude in the United States to the east of the Continental Divide. The Centennial Mountain Range and Beaverhead Mountains of the Bitterroot Range, both north of the INEEL, act as an effective barrier to the movement of most of the intensely cold winter air masses entering the United States from Canada. Occasionally, however, cold air spills over the mountains and is trapped in the plain. The INEEL then experiences below normal temperatures for periods lasting from 7 to 10 days. The relatively dry air and infrequent low clouds permit intense solar heating of the surface during the day and rapid radiant cooling at night. These factors combine to give a large diurnal range of temperature near the ground. The average summer daytime maximum temperature is 28°C (83°F), while the average winter daytime maximum temperature is −0.6°C (31°F). During a 38-year period of meteorological records (1950 through 1988) from the CFA, temperature extremes at the INEEL have varied from a low of −44°C (−47°F) in January to a high of 38°C (101°F) in July (Clawson, Start, and Ricks 1989).

2.2.2.3 Humidity. Data collected from 1956 through 1961 indicate that the average relative humidity at the INEEL ranges from a monthly average minimum of 18% during the summer months to a monthly average maximum of 55% in the winter. The relative humidity is directly related to diurnal temperature fluctuations. Relative humidity reaches a maximum just before sunrise (the time of lowest temperature) and a minimum in midafternoon (time of maximum daily temperature) (Clawson, Start, and Ricks 1989).

The potential annual evaporation from saturated ground surface at the INEEL is approximately 109 cm (43 in.) with a range of 102 to 117 cm (40 to 46 in.) (Clawson, Start, and Ricks 1989). About 80% of this evaporation occurs between May and October. During the warmest month, July, the potential daily evaporation rate is approximately 0.63 cm/day (0.25 in./day). During the coldest months, December through February, evaporation is low and may be insignificant. Actual evaporation rates are much lower than potential rates because the ground surface is rarely saturated. Evapotranspiration by the sparse native vegetation of the Snake fiver Plain is estimated at between 15 to 23 cm/year (6 to 9 in./year), or four to six times less than the potential evapotranspiration. Periods when the greatest quantity of precipitation water is available for infiltration (late winter to spring) coincide with periods of relatively low evapotranspiration rates (EG&G 1981).

2.2.2.4 Wind. Wind patterns at the INEEL can be quite complex. The orientations of the surrounding mountain ranges and the ESRP play an important part in determining the wind regime. The INEEL is in the belt of prevailing westerly winds, which are channeled within the ESRP to produce a west-southwest or southwest wind approximately 40% of the time. Local mountain valley features exhibit a strong influence on the wind flow under other meteorological conditions as well. The average midspring windspeed recorded at the CFA meteorological station at 6 m (20 ft) was 9.3 mph, while the average midwinter windspeed recorded at the same location was 5.1 mph (Irving 1993). A wind rose based on wind direction and speed data collected at the RWMC meteorological station is provided in Figure 2-4 (Clawson, Start, and Ricks 1989).

The INEEL is subject to severe weather episodes throughout the year. Thunderstorms occur mostly during spring and summer. Tornado probability is about 7.8E-05 per year for the INEEL area (Bowman et al. 1984). An average of two to three thunderstorms occurs during each of the months from June through August (EG&G 1981). Thunderstorms are often accompanied by strong gusty winds that may produce local dust storms. Precipitation from thunderstorms at the INEEL is generally light. Occasionally, however, rain resulting from a single thunderstorm on the INEEL exceeds the average monthly total precipitation (Bowman et al. 1984).

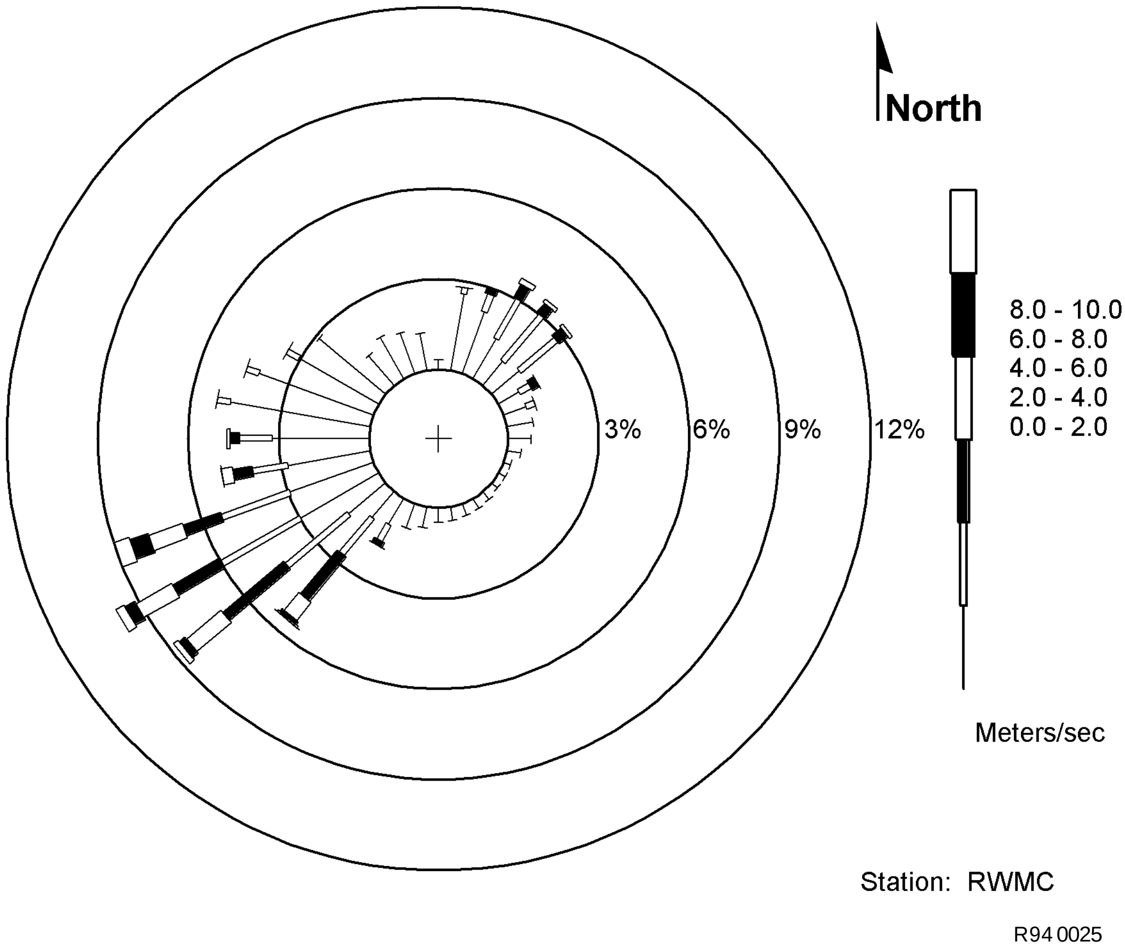

Figure 2-4. Wind rose from the Radioactive Waste Management Complex area for 1980 through 1982.

Dust devils can entrain dust and pebbles and transport them over short distances. Common in the region, dust devils usually occur on warm sunny days with little or no wind. The dust cloud may be several hundred yards in diameter and extend several thousand feet in the air (Clawson, Start, and ficks 1989).

2.2.3 Surface and Subsurface Geology

2.2.3.1 INEEL Surface and Subsurface Geology. The surface of the INEEL is generally covered by Pleistocene and Holocene basalt flows ranging in age from 300,000 to ***3*** million years (Hackett, Pelton, and Brockway 1986). These basalts erupted mainly from northwest-trending volcanic rift zones, marked by belts of elongated shield volcanoes and small pyroclastic cones, fissure-fed lava flows, and noneruptive fissures or small displacement faults (Hackett and Smith 1992). A prominent geologic feature of the INEEL is the flood plain of the Big Lost fiver. Alluvial sediments of Quaternary age occur in a band that extends across the INEEL from the southwest to the northeast. The alluvial deposits grade into lacustrine deposits in the northern portion of the Site where the Big Lost fiver enters a series of playas. Paleozoic sedimentary rocks make up a small area of the INEEL along the northwest boundary. Three large silicic domes (East, Middle, and Big Southern Buttes) occur along the southern boundary of the INEEL, and a number of smaller basalt cinder cones occur across the Site. Mountains of the Lost fiver, Lemhi, and Bitterroot ranges that border the northwest portion of the INEEL are Cenozoic fault-blocks composed of Paleozoic limestone, dolomite, and shale. The northwest trend of the Basin and

Range faults north of the ESRP and at the volcanic rift zones on the ESRP is controlled by the east-northeast direction of regional extension (Smith, Jackson, and Hackett 1996; Parsons, Thompson, and Smith 1998).

Basalt flows in the surface and subsurface at the INEEL were formed by three general methods of plains-style volcanism, which is an intermediate style between the flood basalt volcanism of the Columbia Plateau and the basaltic shield volcanism of the Hawaiian Islands (Greely 1982; Hackett and Smith 1992). The methods are flows forming low-relief shield volcanoes, fissure-fed flows, and major tube-fed flows with other minor flow types. The very low shield volcanoes, with slopes of about 1 degree, formed in an overlapping manner. This overlapping and coalescing of flows is characteristic of the low surface relief on the ESRP (Greely 1982). Considerable variation in texture occurs within individual basalt flows. In general, the bases of basalt flows are glassy to fine grained and minutely vesicular. Midportions of basalt flows are typically coarser grained with fewer vesicles than the top or bottom of the flow. Upper portions of flows are fine grained and highly fractured with many vesicles. This pattern is the result of rapid cooling of the upper and lower surfaces with slower cooling of the interior of the basalt flow. The massive interiors of basalt flows are typically jointed with vertical joints in a hexagonal pattern formed during cooling.

During quiescent periods between volcanic eruptions, sediments were deposited on the surface of basalt flows. These sedimentary deposits display a wide range of grain-size distributions depending on the mode of deposition (i.e., eolian [windblown silt or sand], lacustrine, or fluvial), source rock, and length of transport. Because of the irregular topography of basalt flows, sedimentary materials commonly accumulated in isolated depressions.

A number of wells have been drilled within the INEEL to monitor groundwater levels and water quality. Lithologic and geophysical logs were made for most of the wells. From these logs and an understanding of the volcanism of the Snake fiver Plain, a reasonable comprehensive picture of subsurface geology can be drawn. Figures 2-5 and 2-6 are cross-sections through the SDA area that illustrate the layered geology with thin sedimentary interbeds between large basalt flows.

2.2.3.2 RWMC Surface and Subsurface Geology. The RWMC lies within a natural topographic depression, as illustrated in Figure 2-3. Undisturbed surficial sediments at the RWMC range in thickness from 0.6 to 7.0 m (2 to 23 ft) and consist primarily of fine-grained playa and alluvial material (Kuntz et al. 1994). The near-surface basalt flows at the RWMC erupted from several volcanic vents in the southwestern portion of the INEEL. Most of the lava flows are younger than 500,000 years and originated from vents in the Arco Volcanic Rift Zone. Subsurface drilling investigations indicate that the topmost flow is about 100,000 years old and flowed nearly 24 km (15 mi) from its source vent at Quaking Aspen Butte to the southwest. The first two lava flows from another flow group near the surface are believed to have come from a butte just north of Big Southern Butte (Kuntz et al. 1994). The flow direction of the group is almost due north of the RWMC.

Anderson and Lewis (1989) defined 10 basalt flow groups and seven major sedimentary interbeds underlying the RWMC shown in Figures 2-5 and 2-6. Basalt flows at the RWMC are typical ESRP basalts and occur as layered flow groups. The interbeds consist of generally unconsolidated sediments, cinders, and breccia. Anderson and Lewis (1989) report a maximum measured flow thickness of 12.2 m (40 ft) with averages ranging from 1.5 to 5.2 m (5 to 17 ft). Seven flow groups and three interbeds extend across the RWMC area. The remaining three flow groups and four interbeds are absent in some wells. Using the Anderson and Lewis (1989) nomenclature, the interbeds are called the A-B, B-C, and C-D sedimentary layers, so named for the basalt flow groups (i.e., A, B, C, and D) that bound the layers above and below. The three uppermost sedimentary layers also are commonly referred to as the 30-, 110-, and

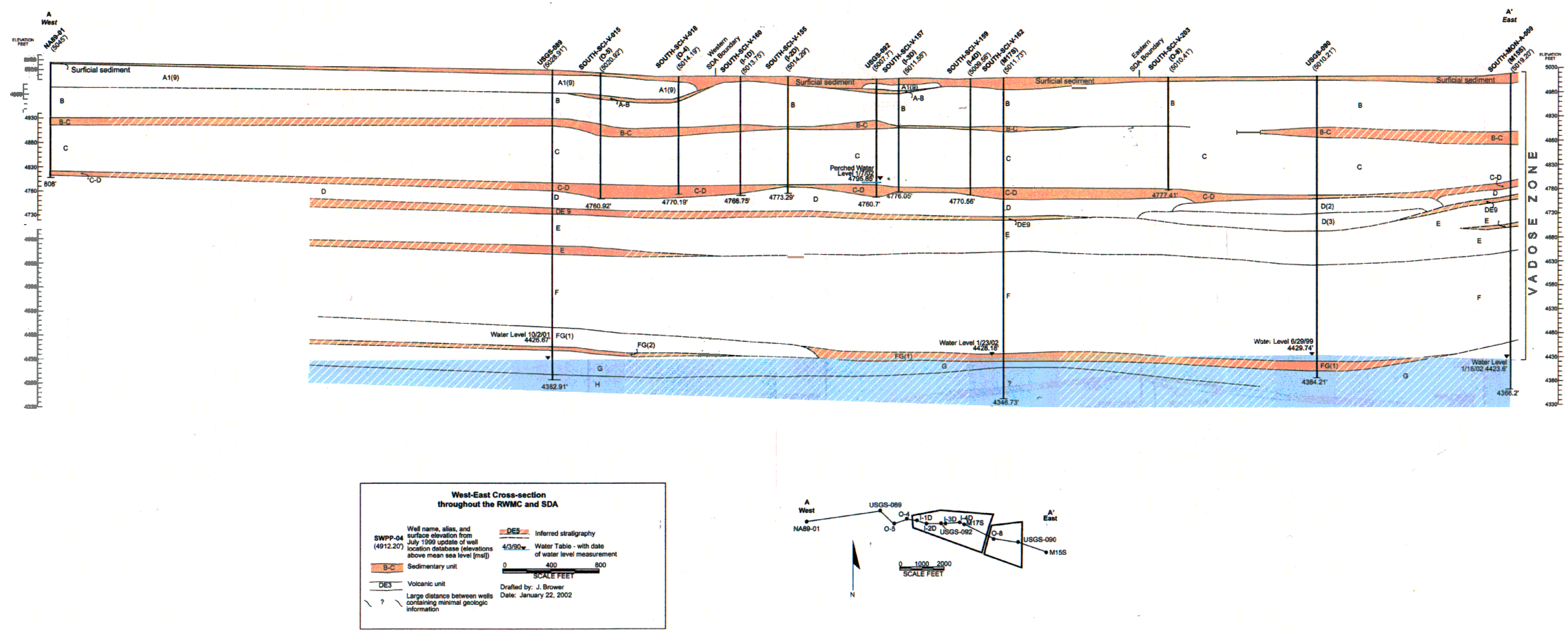

Figure 2-5. Cross section trending west to east through the Subsurface Disposal Area.

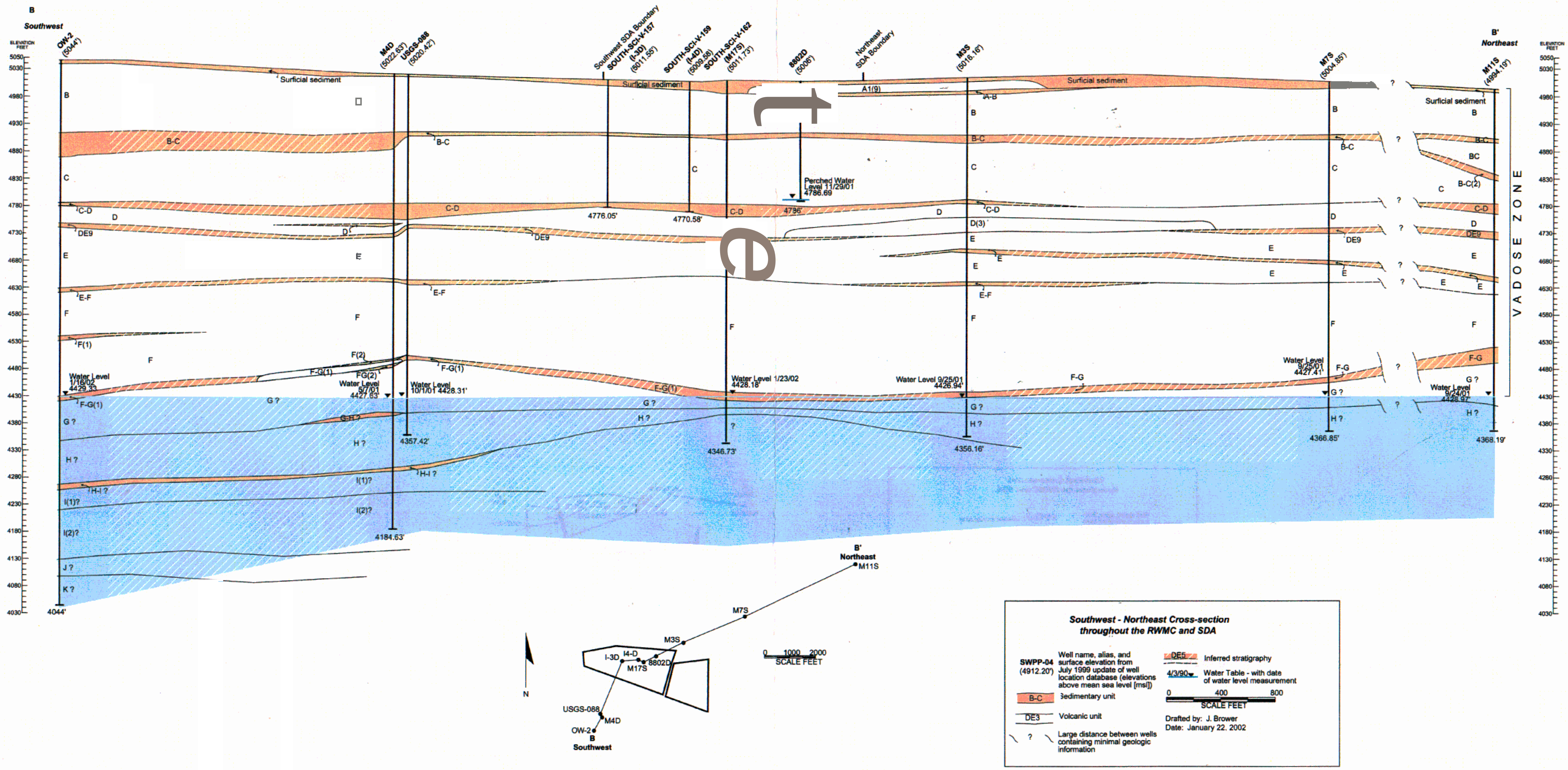

Figure 2-6. Cross section trending southwest to northeast through the Subsurface Disposal Area.

240-ft interbeds. The C-D interbed is by far the most continuous. However, each of the interbeds contains known gaps. The A-B interbed is very discontinuous and generally exists only beneath the northern half of the SDA.

2.2.4 Seismic Activity

Seismic activity in eastern Idaho is concentrated along the Intermountain Seismic Belt, which extends more than 1,287 km (800 mi) from southern Arizona through eastern Idaho to western Montana. The RWMC is subject to the same seismic influences.

The Idaho Seismic Zone extends westward along the Idaho Seismic Belt from the Yellowstone Plateau area into central Idaho. Though several large magnitude earthquakes have occurred in mountain rages surrounding the INEEL, earthquakes beneath the ESRP are rare and have small magnitudes (Jackson et al. 1993). Minor earthquakes have occurred east and north of the INEEL on the ESRP with an average local magnitude of 1.0 on the Richter scale.

The largest earthquake recorded for the Idaho Seismic Zone occurred on October 28, 1983. Measuring 7.3 on the Richter scale, the earthquake epicenter was near Chili Butte, north of MacKay, Idaho. Movement along the range-front fault at the base of the western flank of the Lost Ever Range resulted in uplift of the range on the order of 0.6 m (2 ft), as measured at Borah Peak (Smith, Jackson, and Hackett 1986).

2.2.5 Volcanic Hazards

As discussed above, the INEEL is located in a region of Pleistocene and Holocene volcanic activity, typically characterized by nonviolent effusive basalt lava flows (Hackett and Smith 1992). Four to seven million years ago, explosive rhyolite volcanism occurred beneath the INEEL, forming calderas now buried beneath basalt lava flows. The youngest lava flow in the region immediately surrounding the Site erupted about 4,100 years ago from the Hell's Half Acre Lava Flow to the southeast of the INEEL. The most recent lava flows within the Site boundary occurred 13,000 years ago near the southern boundary — the Cerro Grande flow (Hackett, Pelton, and Brockway 1986).

Renewed explosive rhyolite volcanism at the INEEL is very unlikely. Geological and geochronological data indicate an eastward progression of silicic volcanism. The mantle plume or hotspot assumed responsible for the volcanism now lies beneath Yellowstone National Park. Past patterns of volcanism suggest that future volcanism at the INEEL within the next 1,000 to 10,000 years is very improbable (EG&G 1990). The two most likely sources of future basalt flows on the INEEL are the Arco-Big Southern Butte and the Lava Ridge-Hell's Half Acre volcanic rift zones.

The INEEL Volcanism Working Group (EG&G 1990) estimated the probability of inundation of the RWMC by basalt flows to be much less than 10^{-5} per year. The chief volcanic hazard at RWMC is inundation by lava flows from source vents outside the boundaries of the RWMC (EG&G 1990). In the unlikely event that lava flows inundated the RWMC, the principal effect on the surficial and buried waste would be localized heating to 300°C (572°F) to a depth of less than 3 m (9.8 ft). Other potential effects (i.e., fissuring and gas corrosion) are even more unlikely because the RWMC lies outside known volcanic rift zones (Hackett, Anders, and Walter 1994).

2.2.6 Surface Soil

The INEEL soils are derived from Cenozoic felsic volcanic and Paleozoic sedimentary rocks from nearby mountains. Soils in the northern portion of the INEEL are generally composed of fine-grained lacustrine and eolian deposits of unconsolidated clay, silt, and sand. Typically, soils in the southern INEEL are shallow and consist of fine-grained eolian soil deposits with some fluvial gravels and gravelly sands (EG&G 1988). Across the Site, measured surficial soil thicknesses range from zero at basalt outcrops east of the Idaho Nuclear Technology and Engineering Center (INTEC) to 95 m (313 ft) near the Big Lost fiver Sinks southwest of TAN (Anderson, Liszewski, and Ackerman 1996).

Soils in the RWMC area are polygenetic, meaning they were formed from several types of soil genesis cycles including loess deposition, leaching of calcium carbonate, accumulation of clay, and erosion. The RWMC area is topographically associated with the Big Lost fiver and Big Southern Butte fluvial systems and contains pebble lag within the area of boulder trains, indicating at least one Holocene-age flood from the Big Lost fiver. However, evidence of erosion by these systems during the last 10,000 years following the end of Pinedale glaciation period is not evident.

Physical, chemical, and mineralogical characteristics of the RWMC area soil are detailed in Dechert, McDaniel, and Falen (1994) and McDaniel (1991). Generally, the soil mantling the landscape surrounding the RWMC was deposited as loess during the Pinedale glaciation period and mixed with eolian sand and slope wash in lower areas of the basin. Soil from the RWMC typically has high clay (approximately 36%) and high silt content (approximately 56%) (Chatwin et al. 1992). Generally, the soil has moderate water-holding capacity though some areas of the RWMC have shallow soil with low water-holding capacity (Bowman et al. 1984). Some RWMC soil also may be derived from historic stream deposits from the Big Lost fiver.

Undisturbed surficial deposits within the RWMC area range in thickness from 0.6 to 7.0 m (2 to 23 ft) (Anderson, Liszewski, and Ackerman 1996). Irregularities in soil thickness generally reflect the undulating surface of underlying basalt flows. Many physical features are common within the soil stratigraphy of the RWMC area such as pebble layers, freeze-thaw textures, glacial loess deposits, and platy caliche horizons. Surface soil in the RWMC has been significantly disturbed and recontoured with additional backfill added for subsidence and runoff control.

2.2.7 Surface Hydrology

Surface hydrology at the INEEL includes water from three streams that flow intermittently onto the INEEL and from local runoff caused by precipitation and snowmelt. Most of the INEEL is located in the Pioneer Basin into which three streams drain: the Big Lost fiver, the Little Lost fiver, and Birch Creek. These streams receive water from mountain watersheds located to the north and northwest of the INEEL. Stream flows often are depleted before reaching the INEEL by irrigation diversions and infiltration losses along stream channels. The Pioneer Basin has no outlet; thus, when water flows onto the INEEL, it either evaporates or infiltrates into the ground (Irving 1993).

The Big Lost fiver is the major surface water feature on the INEEL. Its waters are impounded and regulated by Mackay Dam, which is located approximately 6 km (4 mi) north of Mackay, Idaho. Upon leaving the dam, waters of the Big Lost fiver flow southeastward past Arco and onto the ESRP. Flow in the Big Lost fiver that actually reaches the INEEL is either diverted at the INEEL diversion dam to spreading areas southwest of the RWMC or flows northward across the INEEL in a shallow channel to its terminus at the Lost fiver Sinks at which point the flow is lost to evaporation and infiltration (Irving 1993). Because of above-average mountain snow pack in 1995, water in the Big Lost fiver was sufficient during the summer of 1995 to flow to the spreading areas and sinks and to the playas south of TAN. Flow during this timeframe ranged from 13.3 m^3/second (469 ft^3/second) near the RWMC in mid-July to 0.8 m^3/second (29 ft^3/second) in early August (Becker et al. 1996).

The Little Lost fiver drains from the slopes of the Lemhi and Lost fiver ranges. Flow in the Little Lost fiver is diverted for irrigation north of Howe, Idaho, and does not normally reach the INEEL. Springs below Gilmore Summit in the Beaverhead Mountains and drainage from the surrounding basin are the sources for Birch Creek. Flowing in a southeasterly direction between the Lemhi and Bitterroot ranges, the water of Birch Creek is diverted north of the INEEL for irrigation and hydropower during summer. During winter, water not used for irrigation is returned to a channel constructed on the INEEL 6 km (4 mi) north of TAN where the water infiltrates into channel gravels, recharging the aquifer (Irving 1993). Surface water features of the INEEL are illustrated in Figure 2-7.

The RWMC is located within a natural topographic depression with no permanent surface water features (see Figure 2-3). However, the local depression tends to hold precipitation and to collect additional runoff from the surrounding slopes. Surface water within WAG 7 and the surrounding local area does not reach the Big Lost fiver (Keck 1995). Surface water either eventually evaporates or infiltrates to the vadose zone and the underlying aquifer.

Historically, the SDA has been flooded by local runoff at least three times because of a combination of snowmelt, rain, and warm winds. Dikes and drainage channels were constructed around the perimeter of the SDA in 1962 in response to the first flooding event. The height of the dike was increased and the drainage channel around the perimeter was enlarged, following a second flood in 1969. The dike was breached by accumulated snowmelt in 1982, resulting in a third inundation of open pits within the SDA. Significant flood-control improvements included increasing the height and breadth of the dike, deepening and widening the drainage channel, and contouring to eliminate formation of surface ponds and to route runoff to the drainage channel. Localized runoff from surrounding slopes is now prevented from entering the SDA by the perimeter drainage channel and dike surrounding the facility. Runoff from inside the SDA is directed to the perimeter drainage channel where it exits the disposal area. As long as the drainage system is maintained, the existing SDA peripheral drainage ditch and the main discharge channel along Adams Boulevard are adequate to protect the SDA from the 25- and 100-year combined rain and snowstorm events (Dames & Moore 1993).

The Big Lost fiver is not a surface water flow path for contaminant transport at the SDA. Information that supports this conclusion was developed by Keck (1995) and is repeated in the following paragraphs.

The Big Lost fiver, 3.2 km (2 mi) north of the SDA, is at an elevation of 9 to 12 m (30 to 40 ft) higher than the SDA (see Figure 2-3). However, the Big Lost fiver does not pose a flood threat to the SDA. The river is topographically isolated from the SDA and flows northeast away from the facility to its termination in the playas (see Figure 2-3). This position is further supported by the a detailed flood-routing analysis of a hypothetical failure of Mackay Dam resulting from hydrologic and seismic events. The study concluded that severe flooding from the Big Lost fiver would not inundate the RWMC (Koslow and Van Haaften 1986). Big Lost fiver flows have not entered the SDA since operations began in 1952. A mineralogical correlation of surficial sediment from area drainages with sedimentary interbeds suggests that the present day drainage patterns of the streams at the RWMC may be similar to historical patterns (Bartholomay 1990). A plot of the average percentages of total clay minerals plus mica, total feldspar, and carbonates of the sedimentary interbeds indicates that the interbeds at the RWMC are similar to the Big Lost fiver channel, overbank, and spreading area deposits (Koslow and Van Haaften 1986). Similarities indicate that most of the sedimentary interbeds analyzed at the RWMC may be flood plain deposits of an early river containing sediments similar to the present day Big Lost fiver deposits. The correlations suggest that the sedimentary interbeds probably were deposited in a depositional basin similar to the present day basin.

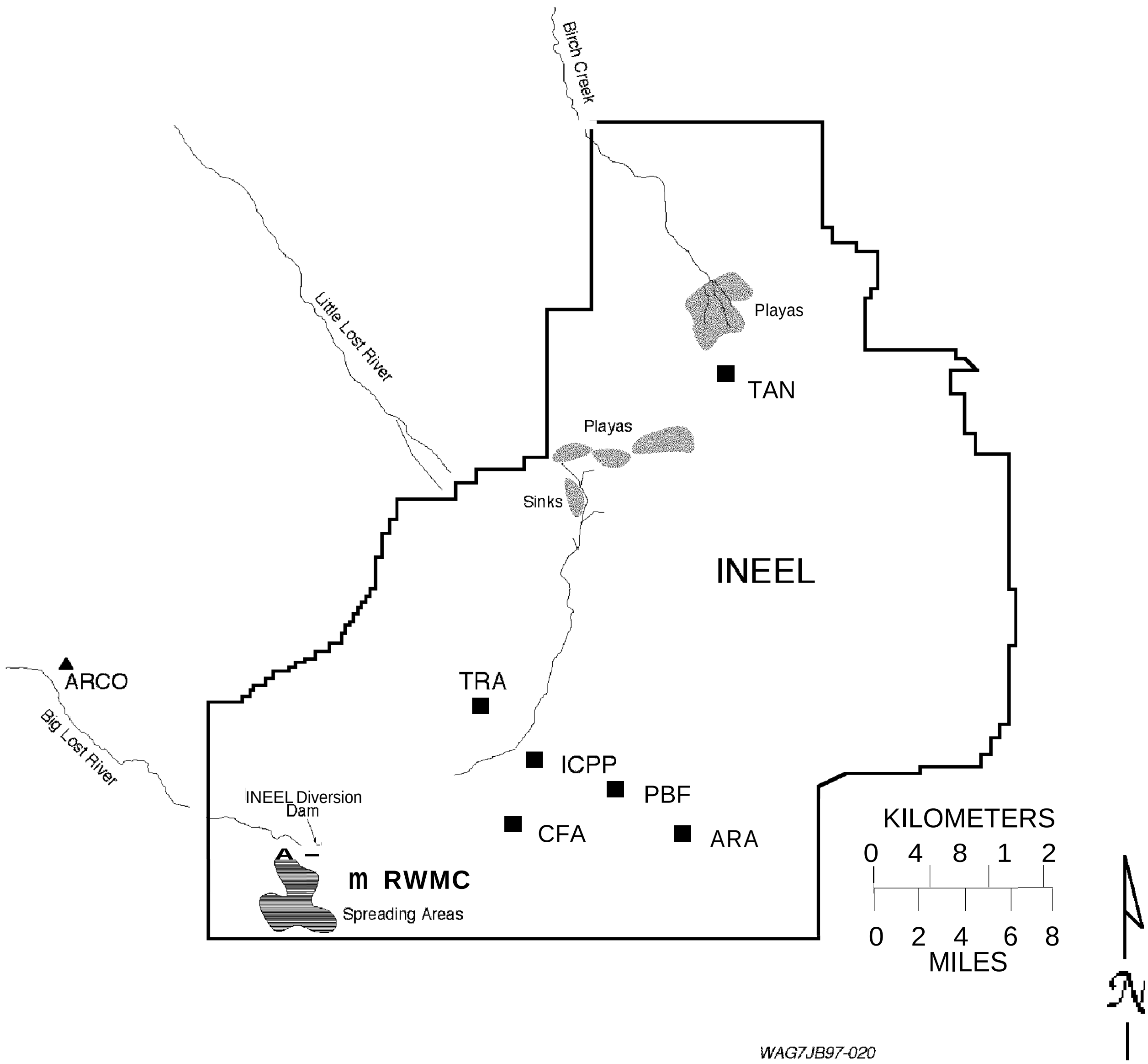

Figure 2-7. Surface water features of the Idaho National Engineering and Environmental Laboratoq

The past 10,000 years (i.e., the Holocene period, which followed the last glacial period) was a period of soil formation and limited erosion in the small valley in which the RWMC is located. The limited erosion probably will continue at least until the next glacial period (Hackett et al. 1995). Regional tributary flooding caused water to enter the RWMC basin on a number of occasions in the Holocene period through the wind gaps in the adjacent Quaking Aspen Butte basalt flow and has left a thin scattering of small (less than 2 mm [0.08 in.]) alluvial gravels just inside the basin near the wind gaps. Evidence indicates that alluvial deposits in the SDA were possibly left during the Pleistocene period and evidence of glacial outburst flooding of the Big Lost River is also from the same geologic period (Rathburn 1989, 1991). Glacial outburst flooding inundated the area that RWMC presently covers during the late Pinedale glacial period (about 20,000 years ago) eroding sediments from higher convex positions around the basin and depositing large basalt boulders within the basin. Nevertheless, substantial soil layers with ages ranging from about 20,000 to 120,000 years remain apparently undisturbed, which indicates that significant erosion of older soil did not occur (Hackett et al. 1995). Climate changes during the approximate 10,000 years after the last glacial period have had little effect on the soil landscape within the RWMC basin. Therefore, it appears that if climate fluctuations are within historical limits, the same may be true for the next 10,000 years.

2.2.8 Subsurface Hydrology

Subsurface hydrology at the INEEL is discussed as three components: the vadose zone, perched water, and the SRPA. The vadose zone, also referred to as the unsaturated zone, extends from the land surface down to the SRPA water table. Water content of the geologic materials in the vadose zone is commonly less than saturation, and water is held under negative pressure. Perched water in the subsurface forms as discontinuous saturated lenses with unsaturated conditions existing both above and below the lenses. Perched water bodies are formed by vertical, and to a lesser extent, lateral migration of water moving away from a source until an impeding sedimentary layer is encountered. The **SRPA,** also referred to as the saturated zone, occurs at various depths beneath the ESRP. About 9% of the **SRPA** lies beneath the INEEL (see Figure 2-1) (DOE-ID 1996). The depth to the water table ranges from approximately 61 m (200 ft) in the northern part of the INEEL to greater than 274 m (900 ft) in the southern part (Irving 1993).

The description of the subsurface geology and hydrology is based on the interpretation of data obtained from drilling and monitoring wells. Some of the wells are limited to the vadose zone while others extend into the SRPA. Table 2-1 presents a list of the formal names of various wells in the RWMC vicinity, along with short names or aliases for many of the wells. Aliases are commonly used in text and illustrations throughout this ABRA.

Table 2-1. Names and common aliases for wells in the vicinity of the Radioactive Waste Management Complex.

Well Name	Common Alias	Well Name	Common Alias	Well Name	Common Alias
76-1	76-1	USGS-105	USGS-105	RWMC-NEU-S-097	NAT-4
76-2	76-2	USGS-106	USGS-106	RWMC-NEU-S-098	NAT-5
76-3	76-3	USGS-108	USGS-108	RWMC-NEU-S-099	NAT-6
76-4	76-4	USGS-109	USGS-109	RWMC-NEU-S-I00	NAT-7
76-4A	76-4A	USGS-I 17	USGS-117	RWMC-NEU-S-101	NAT-8
76-5	76-5	USGS-118	USGS-118	RWMC-NEU-S- 102	NAT-9
76-6	76-6	USGS-119	USGS-119	RWMC-NEU-S- 103	NAT-10
77-1	77-1	USGS-120	USGS-120	RWMC-NEU-S- 104	NAT-11
77-2	77-2	VZT-01	VZT-1	RWMC-NEU-S-105	NAT-12
78-1	78-1	W-03	W03	RWMC-NEU-S- 106	NAT-13
78-2	78-2	W-04	W04	RWMC-NEU-S-I07	NAT-14
78-3	78-3	W-05	W05	RWMC-NEU-S-108	NAT-15
78-4	78-4	W-06	W06	RWMC-NEU-S-I09	NAT-16
78-5	78-5	w-08	W08	RWMC-NEU-S-l 10	NAT-17
79-1	79-1	W-09	W09	RWMC-SCI-S-115	LYS-1
79-2	79-2	W-13	W13	SOUTH-MON-A-001	M11S
79-3	79-3	W-17	W17	SOUTH-MON-A-002	M12S
88-01D	88-01D	w-20	w20	SOUTH-MON-A-003	M13S
88-02D	88-02D	W-23	W23	SOUTH-MON-A-004	M14S
89-01D	89-01D	W-25	W25	RWMC-SCI-V- 153	I-1S
89-02D	89-02D	WWW1	WWW#1	RWMC-SCI-V- 160	I-ID

Table 2-**1. (continued.)**

Well Name	Common Alias	Well Name	Common Alias	Well Name	Common Alias
USGS-093A	USGS-93A	M1SA	M1SA	RWMC-SCI-V-154	1-25
USGS-096B	USGS-96B	M3S	M3S	RWMC-SCI-V-155	i-2d
D-02	DO-2	M4D	M4D	RWMC-SCI-V-156	I-3S
D-06	D06	M6S	M6S	RWMC-SCI-V- 157	1-3d
D-06	DO-6	M7S	M7S	RWMC-SCI-V- 158	I-4S
D-06A	D-06A	M10S	M10S	RWMC-SCI-V-159	1-4d
D-06A	DO-6A	C1	c -I	RWMC-SCI-V-161	I-5S
D-10	D-10	CIA	C-1A	RWMC-SCI-V-16l	I-5S/D
D-15	D-15	9301	93-01	IWMC-MON-A-162	M17S
EBR-1	EBR-I	9302	93-02	RWMC-SCI-V-203	0-8
HIGHWAY 3	HWY-3	w-02	w02	SOUTH-SCI-V-014	0-6
NA-89- 1	NA89-1	w-02	w-02	SOUTH-SCI-V-Ol l	0-1
NA-89-2	NA89-2	IWMC-MON-A-013	A11A31	SOUTH-SCI-v-012	0-2
NA-89-3	NA89-3	RWMC-VVE-V-068	2E	SOUTH-SCI-V-013	0-3
PA-01	PA01	RWMC-VVE-V-069	3E	SOUTH-SCI-V-018	0-4
PA-02	PA02	RWMC-GAS-V-073	2 v	SOUTH-SCI-v-015	0-5
RIFLE RANGE WELL	RIFLE RANGE	RWMC-VVE-V-067	1E	SOUTH-SCI-V-016	0-7
T-23	T23	RWMC-VVE-V-07 I	5E	SOUTH-MON-A-010	M16S
TH-02	TH02	RWMC-VVE-V-070	4E	SOUTH-MON-A-009	M15S
TH-04	TH04	RWMC-GAS-V-072	1V	VVE 1	VVE 1
TH-05	TH05	RWMC-GAS-V-074	3 v	VVE 3	VVE 3
TW-1	TW-1	RWMC-GAS-V-075	4 v	VVE 4	VVE 4
USGS-009	USGS-9	RWMC-GAS-V-076	5V	VVE 6	VVE 6
USGS-086	USGS-86	RWMC-GAS-V-077	6V	VVE 7	VVE 7
USGS-087	USGS-87	RWMC-GAS-V-078	7V	VVE 10	VVE 10
USGS-088	USGS-88	RWMC-GAS-V-079	8V		98-1
USGS-089	USGS-89	RWMC-GAS-V-080	9 v		98-2
USGS-090	USGS-90	RWMC-GAS-V-081	10V		98-3
USGS-091	USGS-91	RWMC-MON-A-065	ow-1		98-4
USGS-092	USGS-92	RWMC-MON-A-066	ow-2		98-5
USGS-093	USGS-93	RWMC-OBS-A-084	LSIT TEST WELL	PA-03	PA-03
USGS-094	USGS-94	RWMC-NEU-S-094	NAT-1	PA-04	PA-04
USGS-095	USGS-95	RWMC-NEU-S-095	NAT-2		
USGS-096	USGS-96	RWMC-NEU-S-096	NAT-3		

2.2.8.1 Vadose Zone. The vadose zone, defined as the unsaturated region between land surface and an underlying aquifer, or the water table, is a particularly important component of the INEEL hydraulic system for three primary reasons. First, the thick vadose zone affords protection to groundwater by acting as a filter and preventing many contaminants from reaching the SRPA. Second, the vadose zone acts as a buffer by providing storage for large volumes of liquid or dissolved contaminants that have spilled on the ground, migrated from disposal pits and ponds, or have otherwise been released to the environment. Third, the transport of contaminants through the thick, mostly unsaturated materials can be slow if low infiltration conditions prevail.

An extensive vadose zone exists at the INEEL ranging in thickness from 61 m (200 ft) in the north at TAN to greater than 274 m (900 ft) near the southern INEEL boundary. The vadose zone consists of surficial sediments, relatively thin horizontal basalt flows, and occasional interbedded sediments (Irving 1993). Surface sediments in the vadose zone include clays, silts, sands, and some gravels. Thick surficial deposits of clays and silts are found in the northern part of the INEEL, but the deposits decrease in thickness to the south where some basalt is exposed at the topographic surface. Approximately 90% of the vadose zone is composed of thick sequences of interfingering basalt flows. These sequences are characterized by large void spaces resulting from fissures, rubble zones, lava tubes, undulatory basalt-flow surfaces, and fractures. Sedimentary interbeds found in the vadose zone consist of sands, silts, and clays and are generally thin and discontinuous. Sediments may be compacted because of subsequent overburden pressures. Under unsaturated conditions with limited water, flow will move preferentially through small openings in sediment or basalt, avoiding large openings.

The vadose zone thickness near the RWMC, based on recent water level measurements, is approximately 180 to 186 m (590 to 610 ft). The water content of the geologic materials in the vadose zone is commonl) less than saturation and the water is held under negative pressure. Rates of moisture movement in sediments and basalt under varying moisture conditions have been quantified near WAG 7. These quantified rates vary widely and depend on the location, material type, and timing of infiltration at the surface. In Hubbell (1992), elevated magnesium and chloride concentrations measured inside the SDA in perched water Well 8802D suggested that water moved from the surface to a depth of 221 ft in less than 5 years (12 m/year or 40 ftlyear). This conclusion was'based on an assumed solute transport of the magnesium chloride that was applied to the roads in the SDA for dust suppression. Bishop[a] reported wide variations in net drainage from surficial sediments into the underlying basalt over a 3-year period. Net drainage, or recharge, was measured at neutron-probe access tube locations in the SDA and ranged from a high of 49.4 cmlyear (19.5 in./year) to less than 0.3 cmlyear (0.1 in/year). The wide range in recharge was attributed to yearly changes in accumulated snowfall, spring drainage patterns of runoff and ponding, and proximity of the measurement locations to areas of runoff or ponding. A moisture movement rate of 5 m/day (16 ft/day) was measured from land surface to a depth of 55 m (180 ft) through the fractured basalt medium during the aquifer pumping and infiltration test in the summer of 1994 (Porro and Bishop 1995). The infiltration test was conducted approximately 2.1 km (1.3 mi) south of the RWMC. Additional results from the large-scale aquifer stress and infiltration tests are reported in Starr and Rohe (1995); Burgess (1995); Dunnivant, Mecham, and Giles (1995); Newman and Dunnivant (1995); Pfeifer and Anderson (1995); and Porro and Bishop (1995).

2.2.8.2 Perched Wafer. Perched water at the INEEL forms when a layer of dense basalt or fine sedimentary materials occurs with a hydraulic conductivity that is sufficiently low so that downward movement of infiltrating water is restricted. Once perched water develops, lateral movement of the water

a. Bishop, C. W., Interdepartmental Communication to D. J. Kuhns, December 18, 1996, "Pad A Horizontal Hole Neutron Monitoring," CWB-16-96, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

can occur, perhaps by up to hundreds of meters. When perched water accumulates, the hydraulic pressure head increases and water flows through the less permeable perching layer and continues its generally vertical descent. If another restrictive zone is encountered, perching again may occur. The process can continue, forming several perched water bodies between the land surface and water table. The volume of water contained in perched bodies fluctuates with the amount of recharge available from precipitation, surface water, and anthropic sources such as evaporation ponds. Perching behavior tends to slow the downward migration of percolating fluids that may be flowing rapidly under transient near-saturated conditions through the vadose zone. Historically, perched water has been found beneath the RWMC, ANL-W, Test Reactor Area (TRA), and INTEC.

Perched water is transitory beneath the RWMC but has been detected in 11 boreholes at various times. Typically, perched water wells are dry or contain so little water that the volume collected for analysis is limited. Perched water bodies have been identified at two depth intervals at WAG 7, at depths of approximately 24 to 27 m (80 to 90 ft) and 61 to 67 m (200 to 220 ft), corresponding to the sedimentary B-C and C-D interbeds, respectively. Perched water typically occurs in fractured basalt above the interbeds. Locations where perched water or elevated moisture contents have occurred in association with the B-C and C-D interbeds are shown in Figures 2-8 and 2-9, respectively.

The two locations where perched water has been most frequently observed in association with the B-C interbed are Wells 78-1 and 10V. From 1992 to about May 1995, Well 78-1 showed perched water thicknesses of up to 0.3 m (0.9 ft) based on measurements made with steel tapes. Well 78-1 was rebuilt in November 1995 because of questions on the origin of perched water in the well. Well 78-1 has been checked quarterly for perched water since 1997, but none has been observed. Well 10V drilled in the western part of the SDA in 1994 had perched water with measured thickness of 0.2 to 0.4 m (0.8 to 1.2 ft). This well has not been regularly monitored for water; therefore, the persistence of perched water in that location cannot be assessed. This well was completed as a vapor monitoring well and is not designed to collect water samples or water level measurements.

The two wells associated with the C-D interbed that have consistently had perched water are Well USGS 92 located near the center of the western half of the SDA, and Well 8802D located in the northeast part of the SDA (McElroy 1996). Perched water-level monitoring also is reported in perched groundwater monitoring reports by Hubbell (1993, 1995). Well USGS 92 is the only well that routinely yields a perched water sample. A sample has been collected only once from Well 88-02D since 1997.

Sources of perched water at the RWMC may be: (a) surficial infiltration, (b) water moving laterally from the spreading areas of the Big Lost Ever, or (c) a combination of sources. The four lined sewage evaporation ponds located approximately 400 ft south of the RWMC should not be a source for perched water. Two of the evaporation ponds collect sanitary wastewater from the current RWMC operations and are lined with an impermeable plastic membrane. The remaining two ponds were built to support Pit 9 remediation and have compacted soil liners. These two ponds have not been used (INEEL 2001a). A tracer test conducted by the USGS confirmed that at least some of the perched water in Well USGS 92 beneath the RWMC originated from the spreading areas (Nimmo et al. 2002) (see Section 2.3.3.1).

2.2.8.3 ***Snake River Plain Aquifer.*** The SRPA is defined as the saturated portion of a series of basalt flows and interlayered pyroclastic and sedimentary materials that underlie the ESRP. On the west the aquifer extends from Bliss, Idaho, and the Hagerman Valley to Ashton, Idaho, and the Big Bend Ridge on the northeast. Lateral boundaries formed at the points of contact of the aquifer with less permeable rocks at the margins of the plain. The SRPA arcs approximately 354 km (220 mi) through the eastern Idaho subsurface and varies in width from approximately 80 to 113 km (50 to 70 mi). The total area of the SRPA is estimated at 24,862 km^2 (9,600 mi^2). The general features of the SRPA beneath the INEEL and the RWMC are described below.

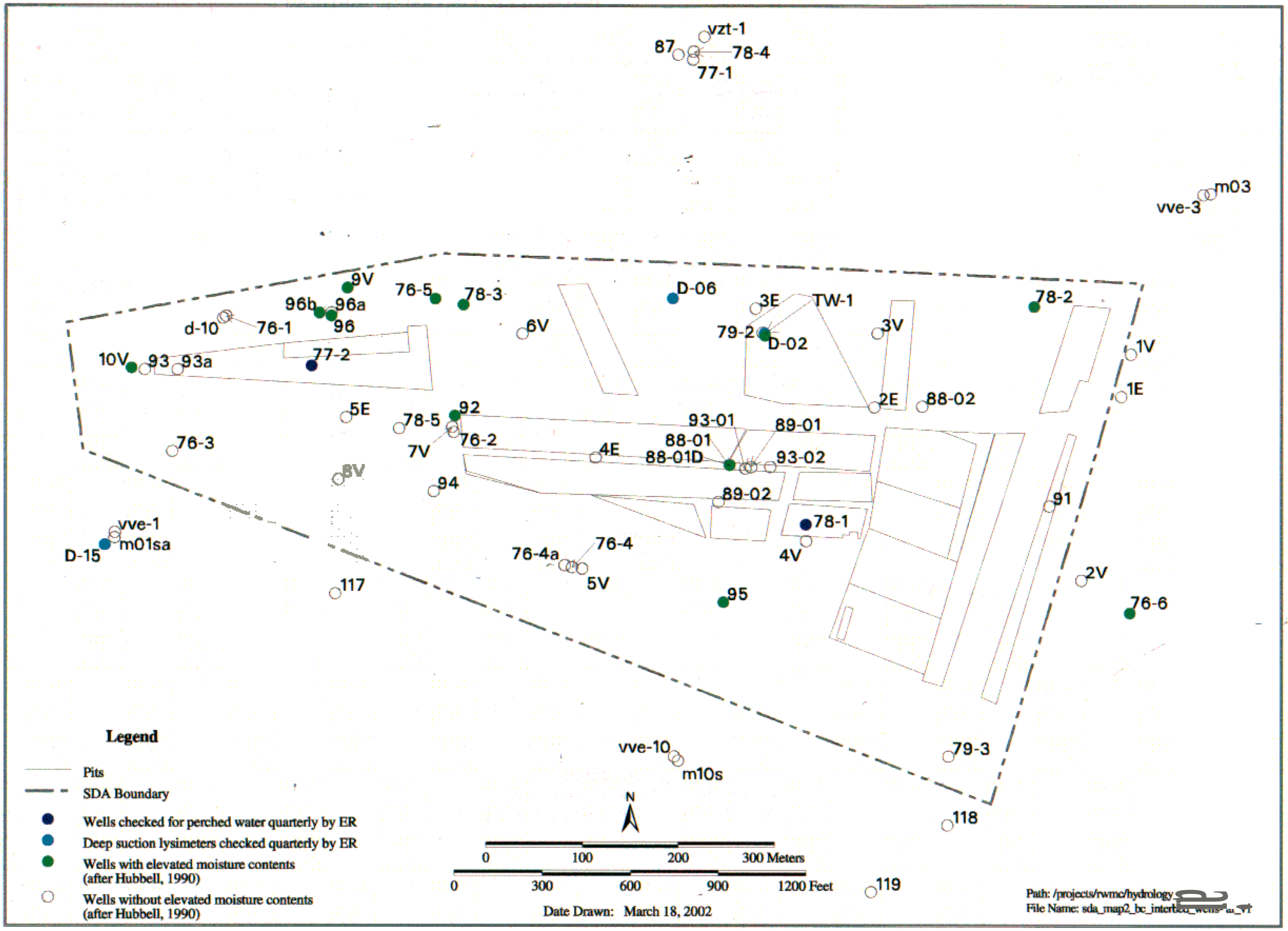

Figure 2-8. Locations with elevated moisture above the B-C interbed.

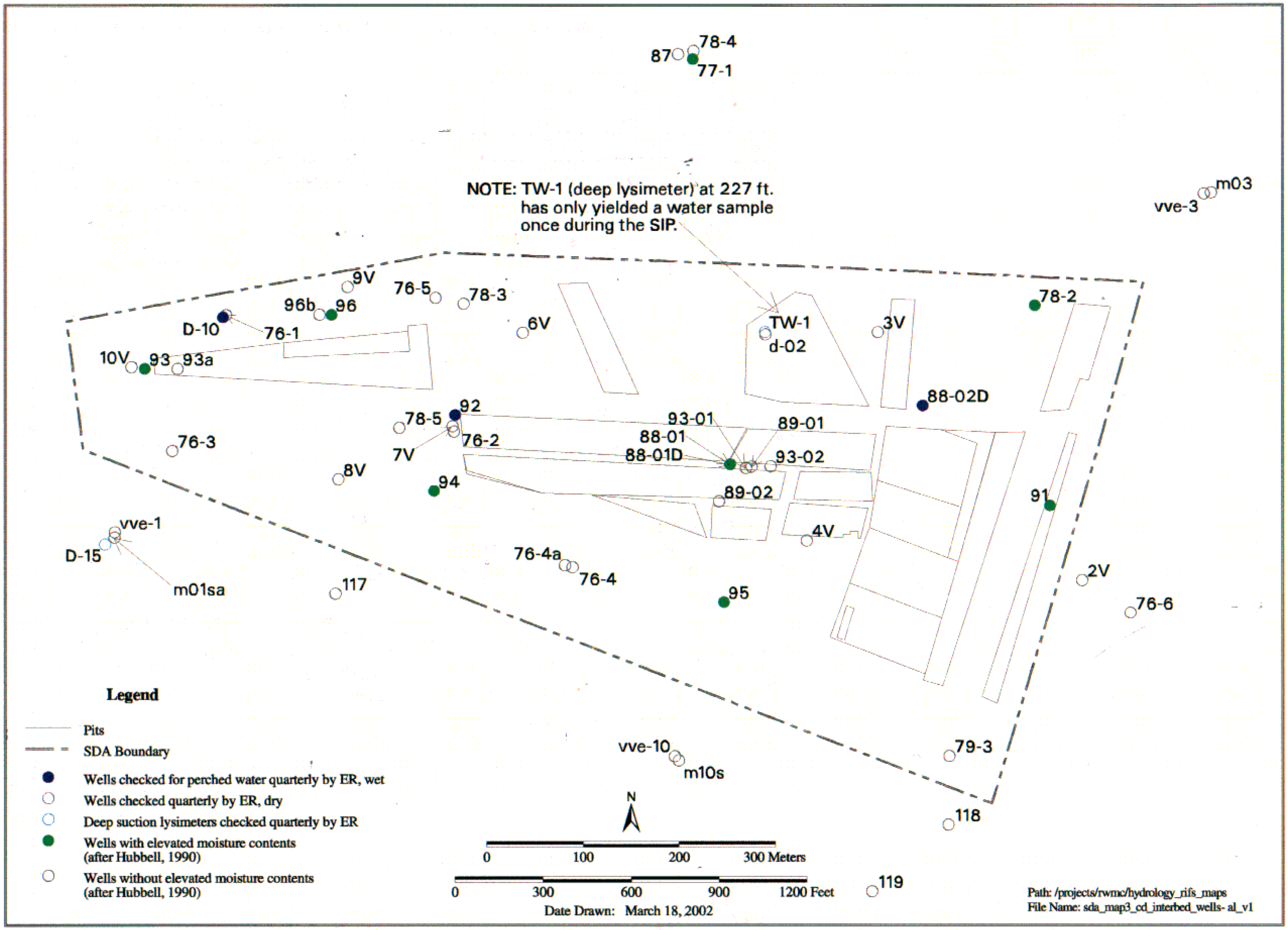

Figure 2-9. Locations with elevated moisture above the C-D interbed.

2.2.8.3.1 Features of the Aquifer Beneath the Idaho National Engineering and Environmental Laboratory—The depth to groundwater at the INEEL ranges from approximately 61 m (200 ft) below land surface in the north to more than 274 m (900 ft) in the south (Becker et al. 1996). The aquifer contains numerous, relatively thin basalt flows extending to depths of 1,067 m (3,500 ft) below land surface. In addition, the SWA contains sedimentary interbeds that are typically discontinuous. The SWA has been estimated to hold 2.5E+12 m^3 (8.8E+13 ft') of water, which is approximately equivalent to the amount of water contained in Lake Erie, or enough water to cover the entire state of Idaho to a depth of 1.2 m (4 ft) (Hackett, Pelton, and Brockway 1986). Water is pumped from the aquifer primarily for human consumption and irrigation (Irving 1993). Compared to such demands, the INEEL's use of the aquifer is minor.

Aquifer permeability is controlled by the distribution of highly fractured basalt flow tops, interflow zones, lava tubes, fractures, vesicles, and intergranular pore spaces. The variety and degree of interconnected water-bearing zones complicate the direction of groundwater movement locally throughout the aquifer. The permeability of the aquifer varies considerably over short distances, but generally, a series of basalt flows includes several excellent water-bearing zones.

The SWA is recharged primarily by infiltration from rain and snowfall that occurs within the drainage basins surrounding the ESW and from deep percolation of irrigation water. Annual recharge rates depend on precipitation, especially snowfall. Regional groundwater flows to the south-southwest, though locally the flow direction can be affected by recharge from rivers, surface water spreading areas, and heterogeneities in the aquifer. Estimates of flow velocities within the SWA range from between 1.5 to 6.1 m/day (5 to 20 ft/day) (Irving 1993). Flow in the aquifer is primarily through fractures, interflow zones in the basalt, and in the highly permeable rubble zones located at flow tops. The SWA is considered heterogeneous and anisotropic (having properties that differ depending on the direction of measurement) because of the permeability variations within the aquifer that are caused by basalt irregularities, fractures, void spaces, rubble zones, and sedimentary interbeds. The heterogeneity is responsible for the variability in transmissivity (which is a measure of the ability of the aquifer to transmit water) through the SWA. Transmissivities measured in wells on the INEEL range from 1.0E-01 to 1.1E+06 m^2/day (1.1E+00 to 1.2E+07 ft^2/day) (Wylie et al. 1995). In general, water quality is preserved because the extensive vadose zone filters chemicals and pollutants from the irrigation and wastewater that pass through the aquifer. Concerns about groundwater contamination from INEEL operations have prompted an extensive monitoring system over all of the INEEL (Irving 1993).

2.2.8.3.2 Features of the Aquifer Beneath the Radioactive Waste Management Complex—The SWA lies approximately 180 to 197 m (590 to 610 ft) below land surface near the RWMC (Wood and Wylie 1991). The level of the water table and flow rates fluctuate in correspondence with meteorological conditions, season, the volume of discharge to the spreading areas, and other factors. Groundwater levels for the RWMC and upgradient areas as of July 2001 (DOE-ID 2002) are shown on Figure 2-10. Groundwater level data taken in March and April 2000 from wells in the RWMC region were used to construct a water table map for wells in the immediate vicinity of the RWMC (Figure 2-11). Water level data for March and April 2000 were used for the local RWMC map because these data were used to support fate and transport modeling for this ABRA (see Section 5).

Estimating the direction and rate of groundwater flow near the RWMC is complicated by the anisotropic and heterogeneous nature of the ESW basalts. Regional flow direction from CFA to the RWMC generally is northeast to southwest (Figure 2-10). The local groundwater flow direction at the RWMC is north-northeast to south-southwest. The water level map for the RWMC indicates that the groundwater gradient across the site is relatively flat (0.00049 ft/ft from Well M14S to Well USGS-120 and 0.00037 ft/ft from Well M11S to Well USGS-120). In comparison, the regional gradient from

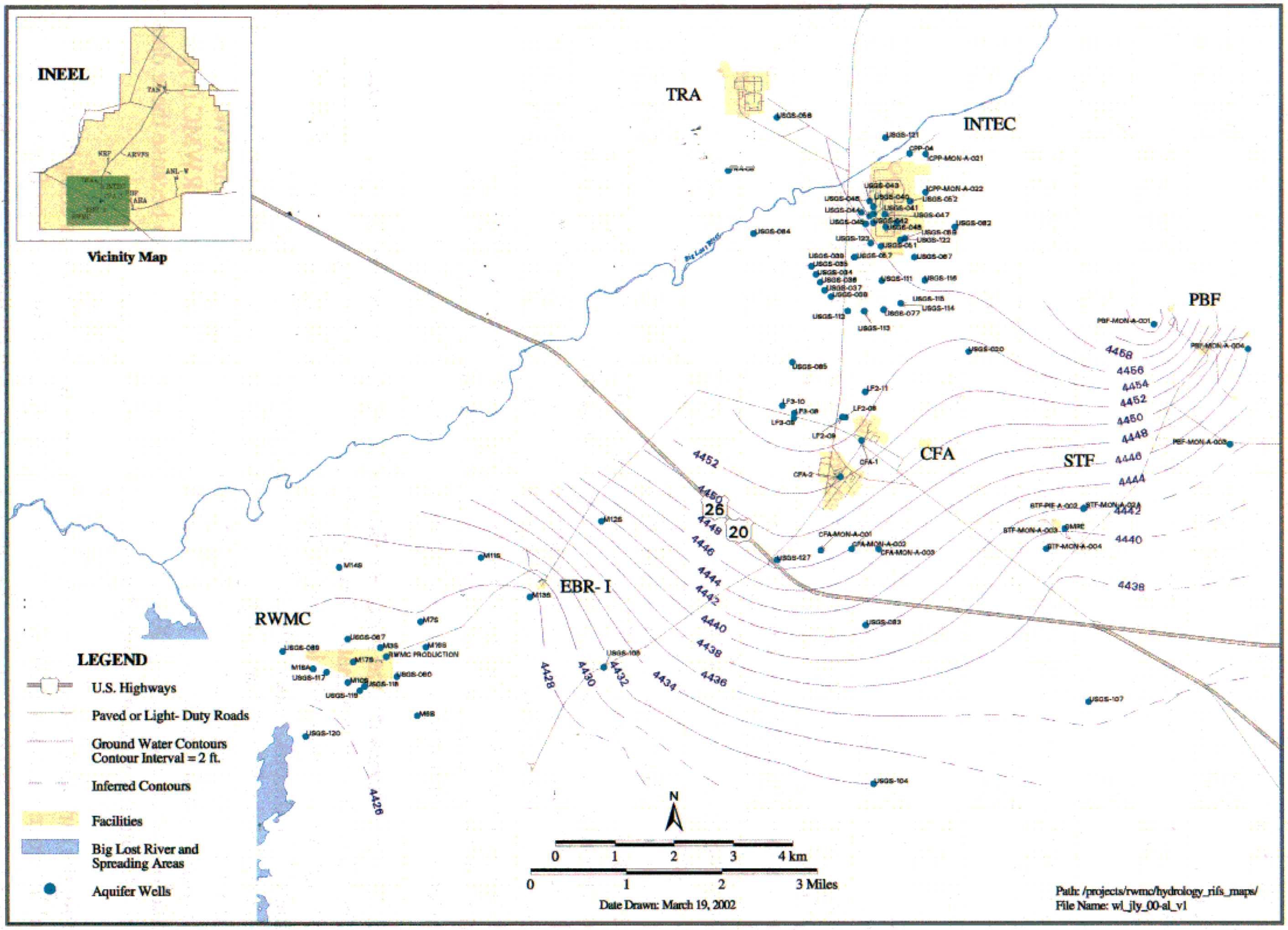

Figure 2-10. Groundwater level measurements for the area upgradient of ∞ Radioactive Waste Management Complex.

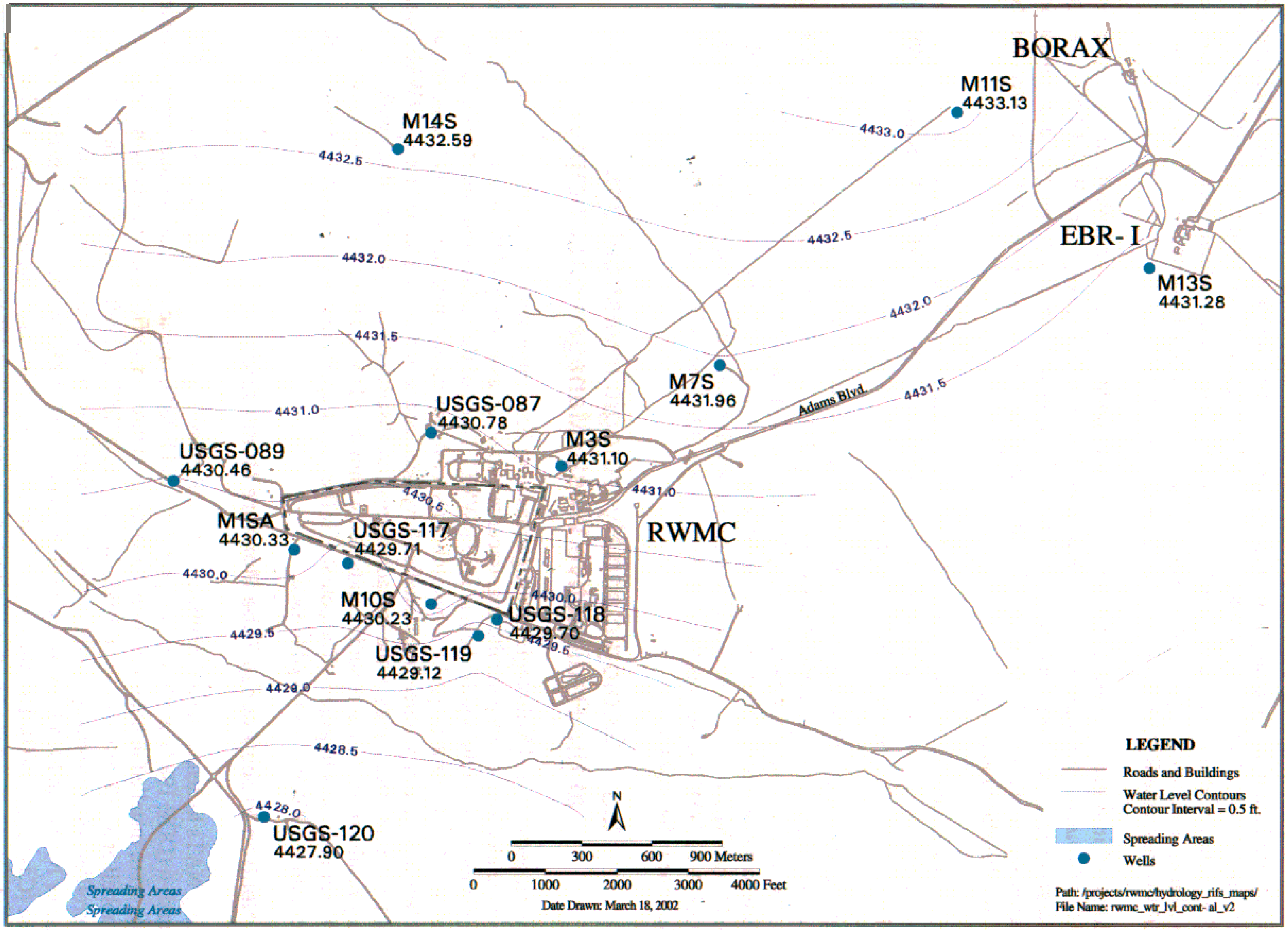

Figure 2-11. Aquifer water level contours in the vicinity of the Radioactive Waste Management Complex based an data collected in March and April 2000.

Well LF3-08 to Well M13S is 0.0016 ft/ft. Pump test results from RWMC wells show that a region of low permeability is present in the RWMC area (Wylie and Hubbell 1994; Wylie 1996).

Local perturbations and seemingly anomalous behavior also have been observed for water levels in the RWMC area (Figure 2-11). For example, Well USGS-88, located directly south of the RWMC, exhibits flow behavior that is not well understood. Water level and pump test data from this well indicate that the well may penetrate a region that is hydraulically isolated from the main body of the active portion of the SRPA beneath the RWMC (Burgess, Higgs, and Wood 1994).

Additional information about hydrological conditions under and near the RWMC was documented in the WAG 7 ***Groundwater Pathway Track 2 Summary Report*** (Burgess, Higgs, and Wood 1994). Results from the large-scale aquifer stress and infiltration tests (Wylie et al. 1995) have been used in a simulation study (Magnuson and Sondrup 1998) to develop the field-scale hydraulic and transport parameters for the OU 7-13/14 subsurface modeling.

Groundwater samples generally are collected on a quarterly basis from 15 wells in the RWMC area to monitor water quality. Wells that are monitored include Wells OW2, M1S, M3S, M13S, M17S, M15S, M6S, A11A31, M4D, M16S, M12S, M11S, M7S, M14S, and USGS-127.

Eight additional aquifer wells, Wells USGS-127, M11S, M12S, M13S, M14S, M15S, M16S, and M17S have been installed since 1998. Wells USGS-127, M11S, M12S, M13S, and M14S are upgradient wells used to evaluate potential inputs of upgradient contamination. The purpose of Wells M16S, M15S, and M17S is to monitor the aquifer for contaminants and flow gradient. Wells South-MON-A-09 (alias M15S) and South-MON-A0010 (alias M16S) were installed outside the RWMC perimeter fence and Well South-MON-A-017 (M17S) was installed inside the fence. All three wells were drilled to the first permeable zone in the aquifer.

2.3 Geologic and Hydrologic Investigations at the Radioactive Waste Management Complex

Several geologic and hydrologic investigations have been implemented over the last several years, including expanded vadose zone monitoring, tracer tests, and an assessment of the influence of upgradient aquifer contamination on the aquifer beneath the RWMC. Three of the vadose zone monitoring networks in place at the RWMC, neutron-probe access tubes (NATs), advanced tensiometers, and lysimeters, are described below. In addition, three tracer studies have been conducted or are planned for the RWMC area. Results of the USGS tracer study at the spreading areas are discussed in this section, along with preliminary results from the tracer study conducted within the SDA and the planned tracer study at the Big Lost River and spreading areas. The potential influence of upgradient aquifer contamination on the aquifer beneath the RWMC also is addressed.

2.3.1 Neutron-Probe Access Tube Moisture Monitoring

Using NATs to determine net infiltration at the RWMC began in 1986 with the installation of NATs-2 and -6 (DOE 1983), as shown in Figure 2-12 and listed in Table 2-2. Carbon steel pipes, open at the bottom, were installed in holes that were hand-augered through surficial sediments to the underlying basalt (Hubbell et al. 1987; Laney et al. 1988; McElroy and Hubbell 1990). Monitoring the NATs for moisture profiles was performed monthly from November 1986 to October 1990. In January 1993, monitoring of NAT-2 and NAT-6 was resumed to support the RWMC low-level waste performance assessment (Case et al. 2000). The objectives of the renewed monitoring were to (a) improve the calibration of neutron counts to moisture content in the sediments and (b) estimate net infiltration into the subsurface from rain and snow at the SDA Monitoring was generally performed on a monthly schedule.

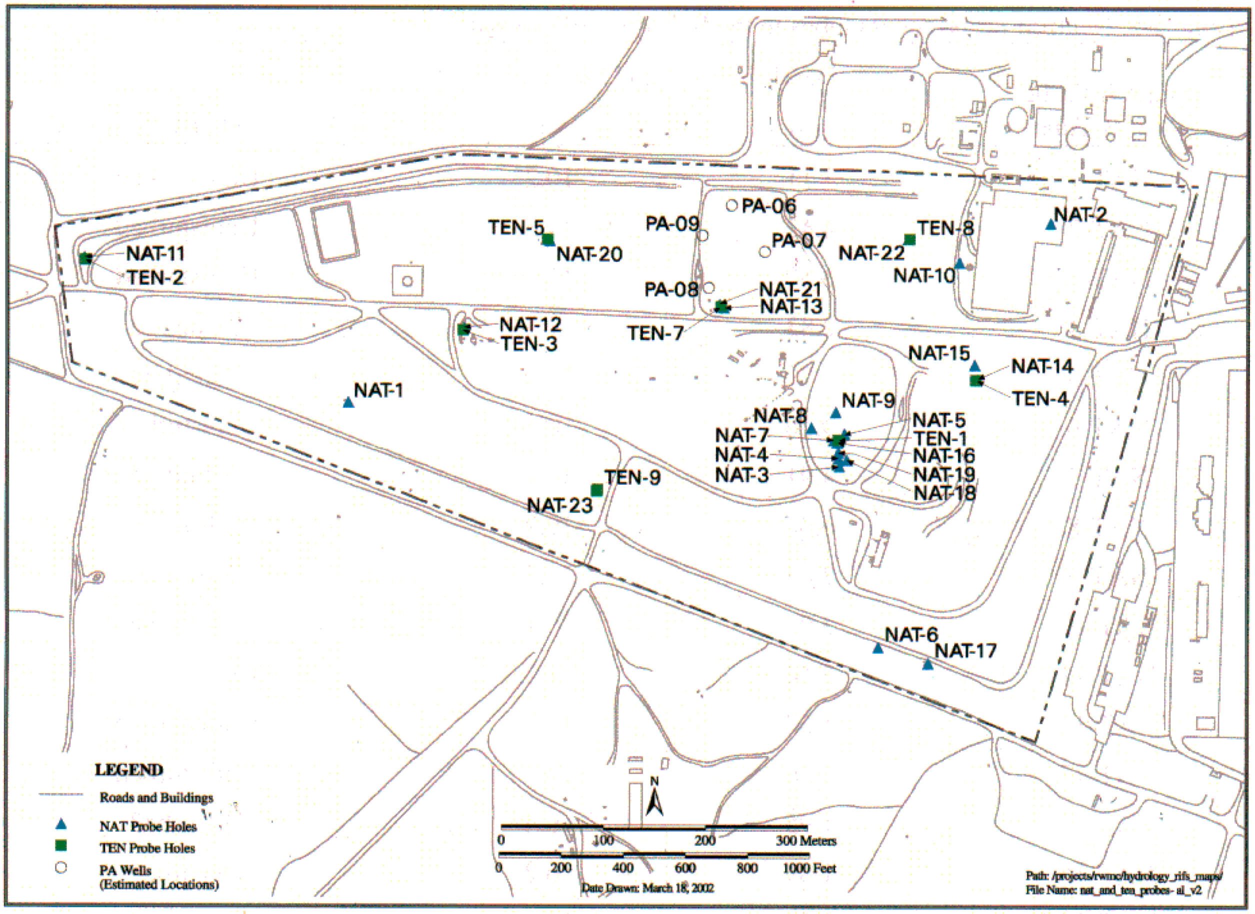

Figure 2-12. Locations of neutron-probe access tubes and associated shallow tensiometers in the Subsurface Disposal Area.

However, monitoring was performed weekly when snowmelt and rain increased the potential for soil moisture changes. Surficial sediment core samples were collected to improve calibrating neutron counts to moisture content in the sediments (McElroy 1993).

The monitoring network was expanded from two to 27 NATs from November 1993 through August 1995 (see footnote a, p. 2-19; Bishop 1994) to improve coverage. In addition, eight boreholes near NATs were instrumented with tensiometers. The NATs and their depths are shown in Table 2-2. The locations of the NATs and associated tensiometer boreholes are shown in Figure 212. Locations were chosen to characterize moisture movement in disturbed and undisturbed areas, near drainage ditches and roads, sway from drainage ditches and roads, and in disturbed cover material over an active waste disposal site.

Monitoring of the NAT network at the SDA was not funded by WAG 7 and ended in August 1996 when the other program discontinued the activity. The NAT monitoring data intermittently span a little more than a decade from 1986 through the summer of 1996. Some additional monitoring of NAT-17 was conducted after 1996 in support of soil gas monitoring for tritium and carbon-14 near a buried beryllium black (Ritter and McElroy 1999).

Table 2-2. Neutron-probe access tubes in the Subsurface Disposal Area.

Neutron-Probe Access Tube	Depth Below Land Surface (m)	(ft)	Disturbed or Undisturbed
NAT-1	3.11	10.2	Undisturbed
NAT-2	4.42	14.5	Undisturbed
NAT-3	3.50	11.5	Undisturbed
NAT-4	2.83	9.3	Disturbed
NAT-5	5.79	19.0	Disturbed
NAT-6	3.20	10.5	Undisturbed
NAT-7	4.91	16.1	Disturbed
NAT-8	6.06	19.9	Undisturbed
NAT-9	7.83	25.7	Disturbed
NAT-10	3.08	10.1	Undisturbed
NAT-11	3.44	11.3	Undisturbed
NAT-12	5.58	18.3	Undisturbed
NAT-13	4.36	14.3	Undisturbed
NAT-14	1.95	6.4	Disturbed
NAT-15	1.89	6.2	Disturbed
NAT-16	5.58	18.3	Disturbed
NAT-17	6.40	21.0	Undisturbed
NAT-18	3.23	10.6	Disturbed
NAT-19	2.99	9.8	Disturbed
NAT-20	3.87	12.7	Undisturbed
NAT-21	4.88	16.0	Undisturbed
NAT-22	3.60	11.8	Undisturbed
NAT-23	2.47	8.1	Disturbed
PA06	1.52	5.0	Disturbed
PA07	1.52	5.0	Disturbed
PA08	1.52	5.0	Disturbed
PA09	1.52	5.0	Disturbed

McElroy (1990) presented net infiltration estimates of at least 10 cm (4 in.) and 13 cm (5 in.) of water at NAT-2 and NAT-6, respectively (see Table 2-3), for an infiltration event in 1989. This 1989 event was chosen because changes in water content of the soil profiles at NATs-2 and -6 in the spring of 1989 indicated that a wetting front extended deep into the soil profile to the surficial sediment/basalt interface. In addition, other instrumentation (e.g., tensiometers, heat dissipation sensors, and gypsum blocks) in surficial sediments at the SDA also indicated that deep recharge had occurred across the SDA in the spring of 1989. Based on vadose zone instrumentation, net infiltration into surficial sediments was determined to be seasonal, occurring primarily in spring when moisture is high and evapotranspiration rates are low. Snowmelt was the major contributor to recharge. Proximity to local low areas, drainage ditches, or areas subject to ponding appeared to increase relative wetness of instrumented sites when compared to locations away from depressions and ditches, or outside the SDA.

Neutron-probe access tube monitoring during 1993 showed a great difference in net infiltration results between NAT-6 and NAT-2 (McElroy 1993). Net infiltration from March through July 1993 at NAT-6 was approximately 27.7 cm (10.9 in.), which was much higher than the 3 cm (1.2 in.) of net infiltration at NAT-2 (Table 2-3). However, net infiltration at NAT-6 may have been influenced by a 1.2 to 1.5-m (4 to 5-ft) -high snow berm located within 1.8 m (6 ft) of the NAT.

To determine the water available for infiltration, snow accumulations were measured and weighed near NAT-6 and NAT-2 on nine occasions to determine the snow water equivalent. All but one of the snow water equivalent values were higher than the cumulative 1992 to 1993 winter precipitation of 12.2 cm (4.8 in.) recorded at CFA. Snow water equivalents ranged from 15.7 cm (6.2 in.) to 22.1 cm (8.7 in.) at NAT-6 and 12.7 cm (5.0 in.) to 20.6 cm (8.1 in.) at NAT-2. The large difference between snow water equivalents and precipitation was attributed primarily to local drifting and accumulation of snow at the SDA, which is influenced by topographic variations such as local depressions, ditches, or snow berms on the sides of roads.

Bishop (see footnote a, p. 2-19) reported wide variations in net infiltration from January 1994 through August 1996 based on the NAT monitoring network that was expanded in 1993. Over the monitored period, measurable net infiltration at the 22 NATs ranged from a high of 49 cdyear (19.4 in./year) to less than 0.3 cdyear (0.1 in./year), as shown in Table 2-3. The wide range in net infiltration was attributed to a combination of variations in snow depth across the SDA, year-to-year variations in accumulated snowfall, spring drainage patterns of runoff and ponding, and proximity of the measurement locations to areas of runoff or ponding.

Bishop (see footnote a, p. 2-19) also evaluated the water equivalent of the snow pack at the SDA. Snow water equivalent samples were collected on February 5, 1996, at 48 locations near the NATs at the SDA. Water equivalents for snow samples ranged from less than 1.3 cm (0.5 in.) to 34.3 cm (13.5 in.) of water, showing large variation in snow accumulation across the SDA. Precipitation from November through January totaled 5.8 cm (2.3 in.) of water, well below the maximum snow water equivalent of 34.3 cm (13.5 in.). However, the average of the 48 samples was 6.6 cm, which is close to the 5.8 cm (2.3 in.) of precipitation received by the end of January 1996.

2.3.1 Advanced Tensiometer Investigation

Advanced tensiometers are instruments that determine water potential at depths greater than the 9-m (30-ft) maximum operating depths achievable by standard tensiometers. A network of advanced tensiometers was installed in and around the RWMC at depths ranging from approximately 6 to 73 m (20 to 240 ft). The objectives of monitoring these deep tensiometers (McElroy and Hubbell 2000) follow:

Table 2-3. Net infiltration estimates based on moisture content changes at neutron-probe access tubes in the Subsurface Disposal Area.

Neutron-Probe Access Tube	1989 (cm)	1993 (cm)	1994 (cm)	1995 (cm)	1996 (cm)
NAT-1	—	—	0.5	1.8	2.8
NAT-2	9.9	23.6	1.3	1.5	—
NAT-3	—	—	1.3	2.8	1.1
NAT-4	—	—	0.3	1.3	0.7
NAT-5	—	—	0.8	1.8	0.4
NAT-6	12.7	55.9	3.0	13.0	1.4
NAT-7	—	—	0.8	2.3	0.9
NAT-8	—	—	1.3	3.3	1.5
NAT-9	—	—	0.3	2.8	0.4
NAT-10	—	—	0.8	2.3	0.7
NAT-11	—	—	2.0	10.7	1.2
NAT-12	—	—	4.8	28.7	6.5
NAT-13	—	—	1.8	48.5	49.4
NAT-14	—	—	0.3	1.3	0.1
NAT-15	—	—	<0.1	1.3	0.4
NAT-16	—	—	0.5	1.3	1.4
NAT-17[a]	—	—	—	—	—
NAT-18	—	—	—	1.3	0.5
NAT-19	—	—	—	0.8	0.6
NAT-20	—	—	—	0.5	2.2
NAT-21	—	—	—	<0.1	4.4
NAT-22	—	—	—	0.8	0.9
NAT-23	—	—	—	0.3	0.1
PA-06	—	—	—	—	0.1
PA-07	—	—	—	—	0.3
PA-08	—	—	—	—	0.4
PA-09	—	—	—	—	0.5

a. **NAT-17** was not monitored on a frequent enough basis to allow calculation of net infiltration
Note: '—' means that the neutron-probe access tube was not monitored.

- Augment, confirm, or change the current conceptual model of water transport in the unsaturated zone beneath the RWMC

- Provide field-scale data for hydrologic model calibration and prediction

- Define soil water conditions within sedimentary interbeds in and around the RWMC before the system is affected by remedial action for the following purposes: develop a baseline description of the water potential in the area, determine long-term status of the water potential beneath the buried waste, detect and monitor movement of wetting fronts to the instrumented depths, and calculate limits for local net infiltration rates

- Detect optimal timing for lysimeter sampling by sensing the presence of soil moisture

- Assess lateral movement of water from the spreading areas in conjunction with planned tracer tests.

2.1.1.1 Advanced Tensiometer Well Locations, History, and Installation. The locations of 20 wells containing the advanced tensiometers are shown in Figure 2-13. Seventeen of the wells were installed and instrumented as part of the WAG 7 OU 7-13/14 hydrologic characterization activities in 2000, and have well names beginning with an O for outside the SDA or an I for inside the SDA. The three remaining wells, 76-5, 77-2, and 78-1, were installed by earlier programs. Well 76-5 was cored in 1976 (Humphrey and Tingey 1978) and was used to monitor perched water until advanced tensiometers were installed in June 1996 (McElroy and Hubbell 2001). Similarly, Wells 77-2 and 78-1 were drilled in 1977 and 1978, respectively, and were used to monitor perched water until advanced tensiometers were installed at interim depths in Wells 77-2 and 78-1 in December 1995. Portable tensiometers were installed at the bottom of both Wells 77-2 and 78-1 in December 1999. Tensiometer depths and the lithology adjacent to each tensiometer are listed in Table 2-4.

2.1.1.2 Advanced Tensiometer Monitoring Results. The advanced tensiometers (see Figure 2-13) indicated steady-state moisture conditions in the subsurface from May through August 2000 with no large-scale infiltration event during that time (McElroy and Hubbell 2001). However, moisture conditions were variable, with water potentials ranging from near saturation (-40 cm of water) to comparatively drier conditions (-350 cm of water).

In contrast, advanced tensiometers in Well 76-5, which cover a vertical profile from 6.7 to 31.4 m (2 to 103 ft), showed that a transient flux of water moved to the 11.6-m (38-ft) depth in March 1999 after 3 years of steady-state conditions (see Figure 2-13). The wetting front moved through the basalt, moving from 6.7 to 11.6 m (2 to 38 ft) in 43 days, which is equivalent to 0.1 m/day (0.3 ft/day) (Hubbell et al. 2002). Water potentials at the 17.4-m (57-ft) depth indicated a slowing of the wetting front, which moved from 11.6 to 17.4 m (38 to 57 ft) over a 5-month period. The sediments and rubble at 11.6 m (38 ft) may have slowed the downward movement of the wetting front.

Table 2-4. Advanced tensiometers at the Radioactive Waste Management Complex.

Tensiometer	Depth (m)	Depth (ft)	Lithology
I1S		103	Interbed
I1D		227	Interbed
12s		94	Basalt (no recovery)
12D		176	Basalt, massive
12D		223	Interbed
I3S		93	Interbed
13D		229	Interbed
I4S		97.5	Basalt-interbed contact
14D		227	Interbed
I5S		–99.7”	Basalt-interbed contact
O1		97	Interbed, no recovery
O1		229	Interbed, no recovery
0 2		107	Basalt-interbed contact
0 2		241.25	Basalt, possibly fractured basalt (lost circulation)
0 3		88	Basal;
0 3		221	Basalt-interbed contact
0 4		110	Interbed
0 4		226.5	Interbed
0 5		105	Basalt
0 6		227	Interbed[b]
0 7		121	Interbed, no recovery
0 7		241	Basalt
0 8		229.5	Basalt
76-5		22	Sediment-filled fractures
76-5		31	Sedimentary interbed
76-5		38	Rubble zone
76-5		57	Horizontal fracture with sediment
76-5		80	Sediment-filled fractures
76-5		97	Moist basalt
76-5		103	Interbed
77-2		32.8	Reddish baked silt interbed
77-2		56	Basalt
77-2		90	Basalt
78-1		35	Fractured basalt, with sediment infilling
78-1		84	Basalt

a. The advanced tensiometer depth in Well I5S was measured after installation and may include some twisting of polyvinyl chloride pipe.
b. Description is based on the gamma log rather than the geologist’s log.

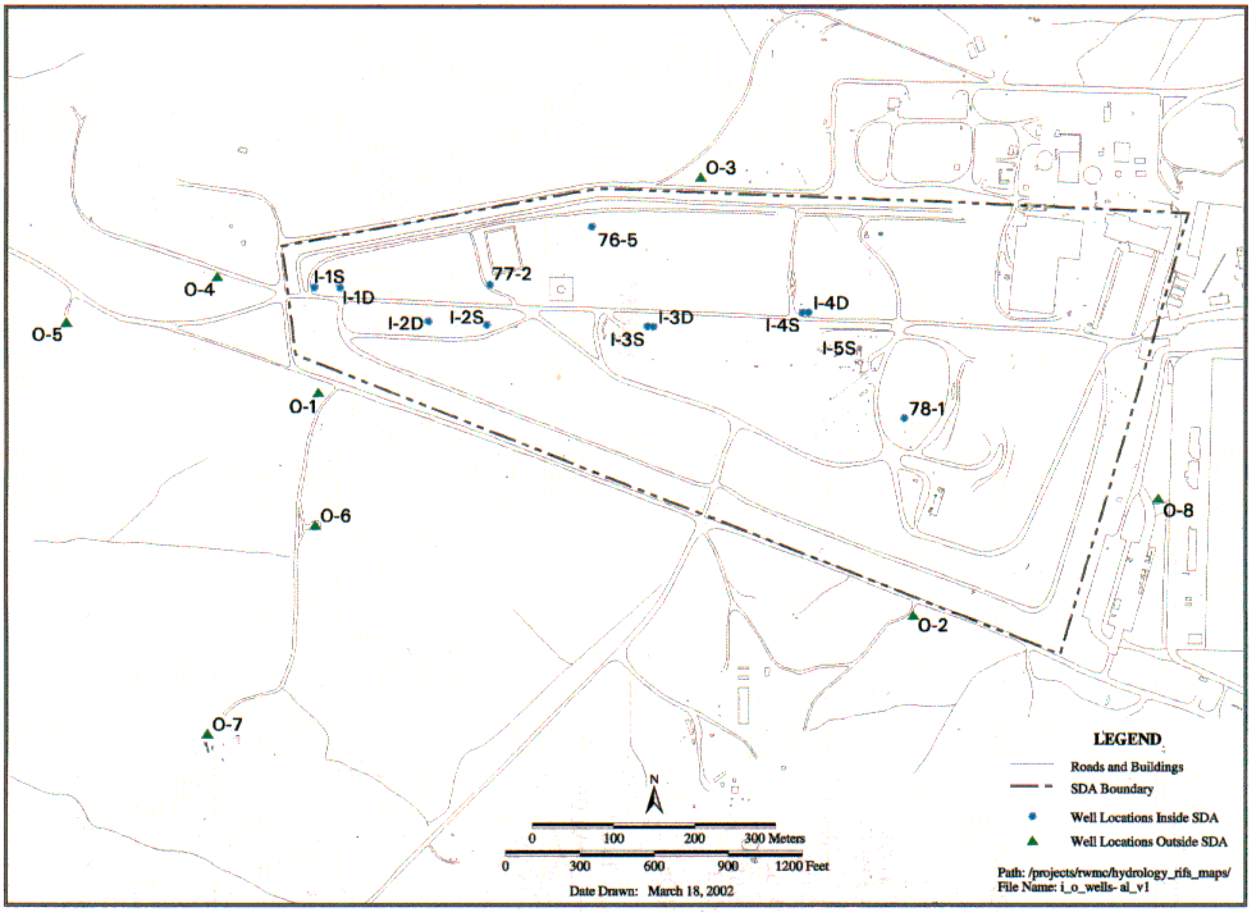

Figure 2-13. Locations of boreholes instrumented with advanced tensiometers at the Radioactive Waste Management Complex.

2.3.2 Lysimeter Investigations

Suction lysimeters are designed to collect moisture from unsaturated soil by creating a vacuum inside the lysimeter and drawing moisture through a porous material into the lysimeter where it can be collected for analysis. The porous material, typically ceramic or stainless steel, contains tiny pores that are permeable to water but impermeable to air when wetted. The majority of the lysimeters at the RWMC have either ceramic or stainless steel cups. Four lysimeters with Teflon cups also were installed because of the hypothesis that radionuclides may sorb on ceramic cups (Hubbell et al. 1985), which could cause biased, low-detection results. The lysimeters with Teflon cups were never successful in collecting soil-water samples because the low air-entry pressure prevented the use of a vacuum that was high enough to extract water from the SDA soil.

Installation of lysimeters at the RWMC began in 1985 to determine solution chemistry and to define radionuclide migration in the vadose zone (Hubbell et al. 1985). From 1985 through 1987, 32 suction lysimeters were installed in surficial sediments in and around the RWMC, and seven deep lysimeters were installed in sedimentary interbeds (Hubbell et al. 1985, 1987; Laney et al. 1988). These lysimeters, L01 through L32 and DL01 through DL07, are listed in Table 2-5, and locations of the boreholes containing the lysimeters are shown in Figure 2-14. Because multiple lysimeters were installed

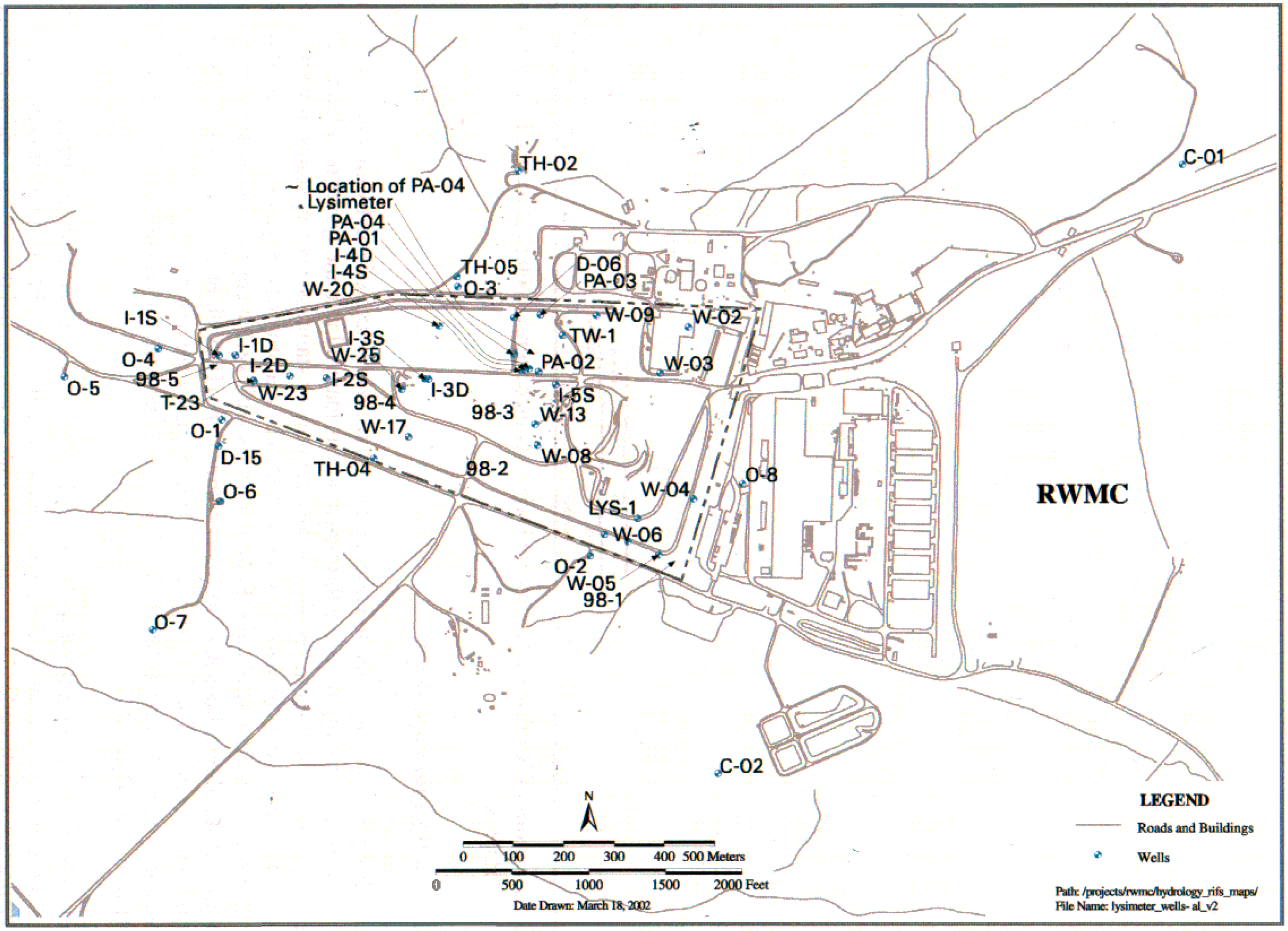

Figure 2-14. Locations of suction lysimeters at the Radioactive Waste Management Complex.